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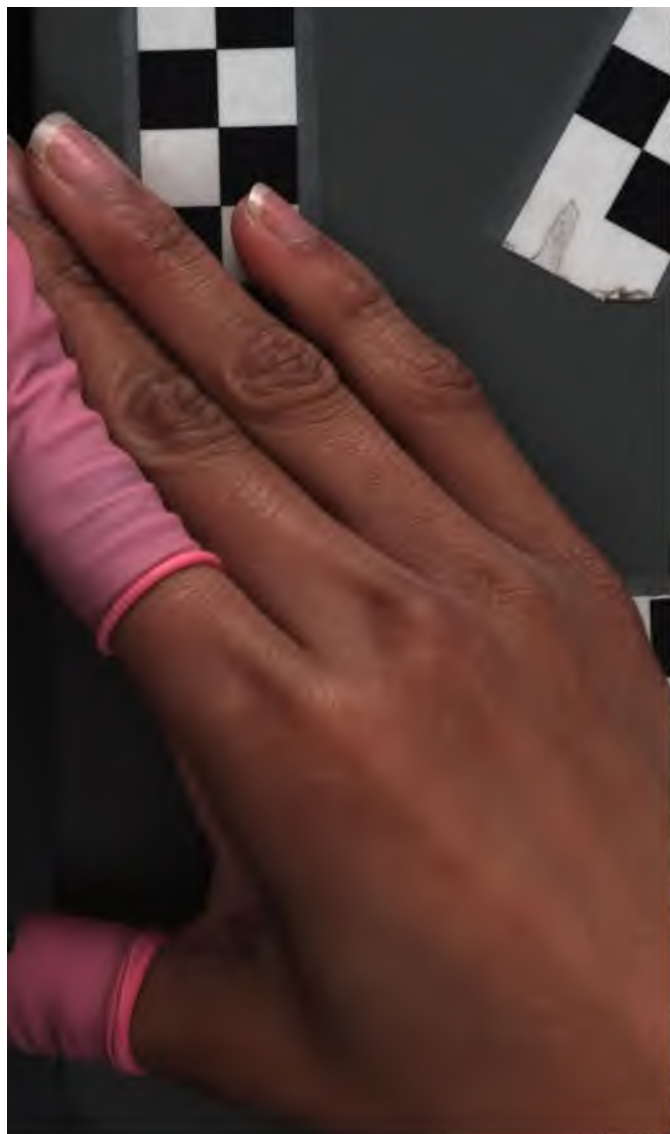
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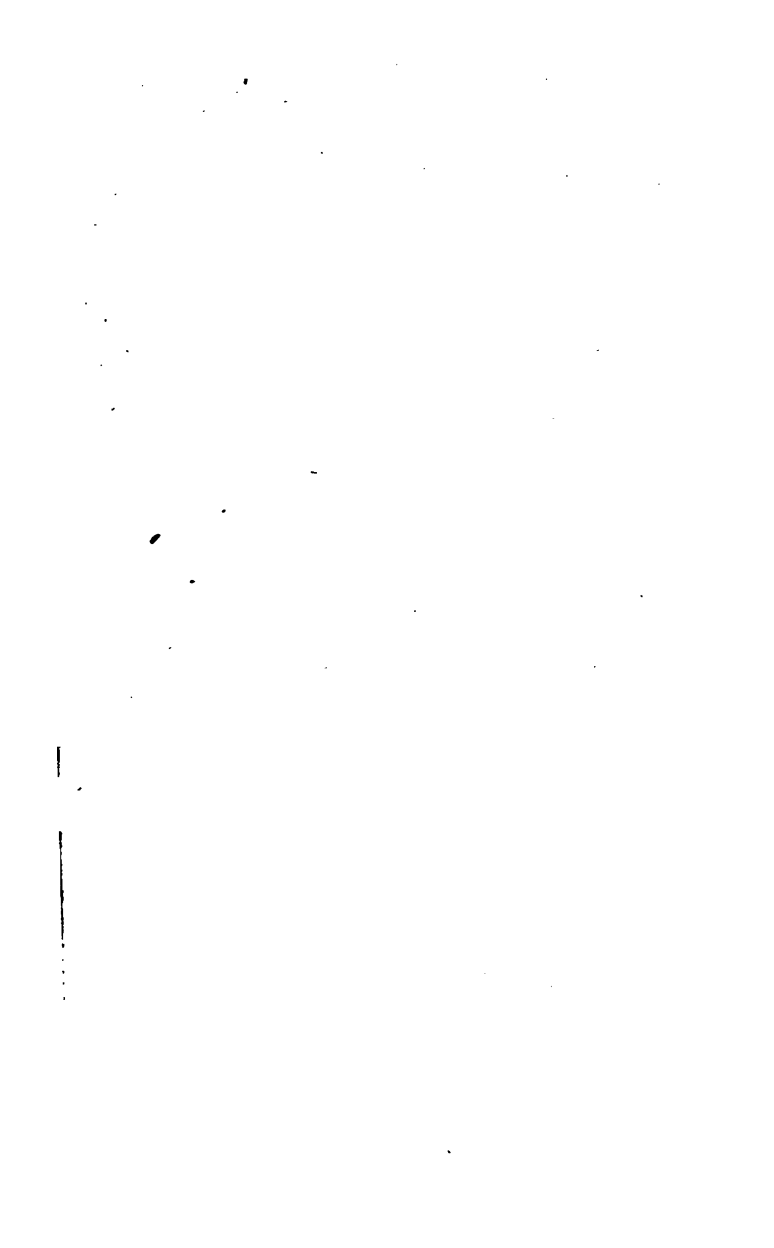




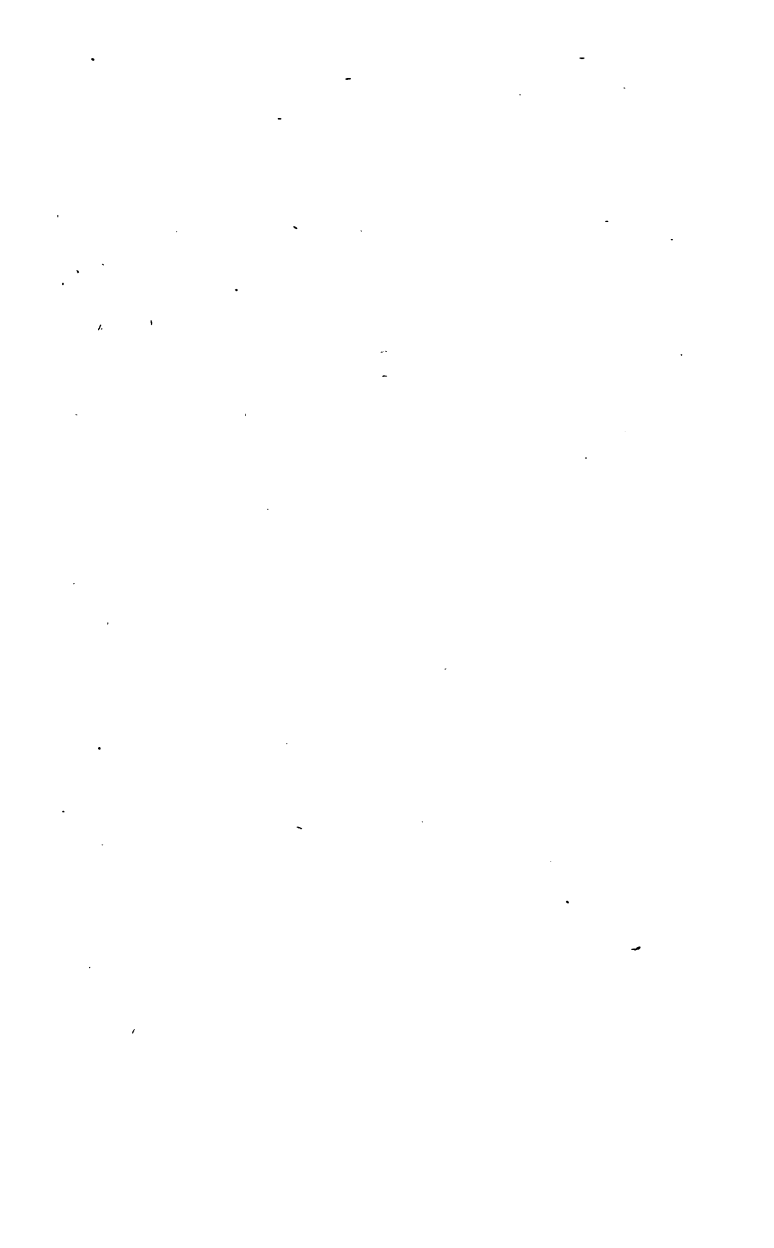
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William Henry Harrison



2000



**THE**  
**ROLLO PHILOSOPHY.**

**PART III.**

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**FIRE.**

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**BY THE**  
**AUTHOR OF THE ROLLO BOOKS.**

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**BOSTON:**  
**PUBLISHED BY OTIS, BROADERS, & CO.**  
**1843.**



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## P R E F A C E .

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THE main design in view, in the discussions which are offered to the juvenile world, under the title of *THE ROLLO PHILOSOPHY*, relates rather to their effect upon the little reader's habits of thinking, reasoning, and observation, than to the additions they may make to his stock of knowledge. The benefit which the author intends that the reader shall derive from them, is an influence on the cast of his intellectual character, which is receiving its permanent form during the years to which these writings are adapted.

The acquisition of knowledge, however, though in this case a secondary, is by no means an unimportant, object ; and the discussion of the several topics proceeds accordingly, with regularity, upon a certain system of classification. This classification is based upon the more obvious external properties and relations of matter, and less upon those

which, though they are more extensive and general in their nature, and, therefore, more suitable, in a strictly-scientific point of view, for the foundations of a system, are less apparent, and require higher powers of generalization and abstraction; and are, therefore, less in accordance with the genius and spirit of the *Rollo* philosophy

As teachers have, in some cases, done the author the honor to introduce some of the preceding works of this class into their schools, as reading books, &c., considerable reference has been had to this, in the form and manner of the discussion, and questions have been added to facilitate the use of the books in cases where parents or teachers may make the reading of them a regular exercise of instruction.

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THE  
ROLLO PHILOSOPHY.

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FIRE.

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CHAPTER I.

SLOW COMBUSTION.

THE way in which it happened that Rollo's father first began to explain to him something about the nature of fire, was this: It was one evening early in the autumn. Dorothy was going away to visit one of her friends, and Rollo was waiting for Jonas to come out, and see the fire-flies, or lightning-bugs, as he called them, which were flying about the yard. But Jonas did not come as soon as Rollo had expected, and so he went into the kitchen to see what had become of him. He found that, as Dorothy was rather late for her visit, and still had her kitchen fire to cover

up, Jonas was just offering to cover it up for her; so that she could go at once without any further delay. So Rollo came in, and stood by the kitchen hearth, to see Jonas cover up the fire.

The fire had nearly burned out, but it had left quite a large bed of embers, and a few coals among them. Jonas took the long-handled iron shovel, which belonged to the kitchen fire, and with it he drew forward all these coals and embers, so as to leave the back part of the hearth bare. Then he took the tongs, and with the tongs he gathered out from the hot ashes all the coals which he could find among the ashes, and put them back upon the bare place which he had made upon the hearth. He spread them evenly over it in a row against the back of the chimney.

"What are you going to do, Jonas?" said Rollo.

"I am going to cover up a stick of wood," replied Jonas.

So Jonas opened a small door which led to a little wood closet by the side of the fire, and took out a short stick of wood, flat on one side and round on the other. It was a stick which was round first, but Jonas had

split it in two. It was part of a great branch of a tree, large enough to make a good log, only Jonas saw that it would split easily, and so he had split it in two. The other half of it was still in the wood closet.

"This is just the stick," said Jonas.

"Why?" asked Rollo.

"Why, the lower side is flat," said Jonas, "to lie upon the coals, and the top is round, so that I can cover it all up the easier."

So Jonas laid the stick down, with the flat side against the coals, and the round side outwards. Then with the great shovel he began to shovel the ashes and embers back over it. He put all the hot embers in first, and then the ashes, and he tried to cover up the stick entirely; but there was not quite ashes enough. One of the ends remained out.

"There, Jonas," said Rollo, "now come."

"No," said Jonas, "I must cover the stick all up."

"O, that little end won't do any harm," said Rollo.

"Yes," said Jonas, "because, when the stick burns down, that place would make a hole, and let too much air in."

"Don't you want any air to get in?" said Rollo.



"Very little," said Jonas. "I want a very slow combustion to go on until to-morrow morning, and then there will be a good bed of coals for Dorothy."

"I don't see why you take so much pains to cover up a stick of wood," said Rollo. "You might light a fire with your tinder-box."

"But it takes a great deal longer to make a good fire with a tinder-box, than when we have a good bed of coals."

"Then take a friction match," said Rollo. "I can light a friction match in half a minute."

"You can light the match, but not build a fire. It takes a long time, with a match light, to get heat enough to set large sticks of wood on fire; but with a bed of burning coals, we can do it very soon."

"You might have some sticks and shavings for kindling," said Rollo, "and they will burn quick."

"Yes," said Jonas, "but it is more trouble to prepare sticks and shavings every night, than it is to cover up a stick of wood."

While Jonas had been saying these things, he had taken more ashes from the ash-hole,

and had covered the stick over entirely. He then put away the shovel, and was brushing up the hearth, when Rollo, after standing a moment, as if in thought, said, —

“Jonas, what do you mean by *combustion*?”

“Did I say *combustion*?” rejoined Jonas.

“Yes, you said you wanted slow *combustion*.”

“Well, I meant burning. I want the wood to burn slowly all night.”

“Then why did not you say *burning*,” said Rollo, “so that I could understand you? I don’t see where you get all your learned words. I suppose it is out of some of your books.”

“Yes,” said Jonas, “they call it *combustion* in the books that I read, but I don’t know exactly why. I think there must be some difference between *combustion* and *burning*, but I don’t know exactly what it is.”

“I mean to ask my father,” said Rollo.

“But do you expect that that stick of wood will burn, Jonas?” continued Rollo, after a moment’s pause.

“Yes,” said Jonas, “it will burn slowly.

A little air will get through the ashes, so as just to keep it burning slowly. It is very dry."

"Suppose that there could not any air get through at all?" said Rollo.

"Why, then," said Jonas, "it couldn't burn at all. It would go out. Sometimes I have buried up a fire so deep in ashes that it has gone out, and then I find nothing but black coals there in the morning, when I rake it open. That's the way they make charcoal."

"How?" said Rollo.

But Jonas had no opportunity to answer this question then, for they were just going out into the yard when Rollo asked it, and the attention of both the boys was attracted to the fire-flies. They, however, soon had looked at the fire-flies as much as they wished. Rollo tried to catch one, but he could not. He would see a flash at a little distance from him, and he would run to the place with his cap in the air; but, by the time that he got there, the fire-fly would of course have gone on to another place, though Rollo could not tell where, without waiting to see him flash again. Then he had to run

again ; but before he got to this second place, the fire-fly would be gone again. One of the fire-flies led him a zigzag chase, in this way, all around the yard, and finally flashed at last just over the garden fence, so that Rollo gave up in despair.

In the mean time, Jonas had gone to the barn ; and now Rollo went to see what had become of him. He found him shutting the doors up for the night, and then they both came back towards the house, and sat down upon the edge of the platform, under the piazza, and Rollo asked Jonas to tell him how they made charcoal.

"Why, they only bury up wood, as I did my log, lightly, so that enough air can get in, until it is burnt through ; and then they cover it up tight, so that no air can get in, and so it goes out ; and when it is all cold, they open it, and find the heap is all black coals."

"How big a heap do they make ?" asked Rollo.

"O, they make a very large heap, sometimes," said Jonas ; "as big as this." So Jonas rose from his seat, and marked out a circle in the yard with a stick, which he had

in his hand, in order to show Rollo how large a heap they make, when they pile up wood for a charcoal bed.

"And how high do they make it?" asked Rollo.

"As high as *that*," said Jonas; and he reached his stick up in the air as high as he could, to show Rollo how high the heap was.

"That must take a great deal of wood," said Rollo.

"Yes," said Jonas; "and when it is turned into charcoal, they get a great many loads of it."

"How do they get ashes enough to cover it up?" asked Rollo.

"O, they don't cover it with ashes," said Jonas; "they cover it with turf."

"With turf?" repeated Rollo.

"Yes," said Jonas. "Turf is the best thing to cover the heap with. If they had ashes, it would be very troublesome to put it on, and then it would be sliding down, and letting the fire break out. But they cut square pieces of turf, and cover the heap all over with them very tight, and so only just air enough gets in to keep the fire slowly burning."



"Slow combustion?" said Rollo.

"Yes, slow combustion," said Jonas.

"How do you set it on fire?" asked Rollo.

"I believe they leave a hole in the middle," said Jonas, "from the top down to the bottom, and then they put the fire down there."

"I wonder if I couldn't make a charcoal bed," said Rollo.

"Yes," replied Jonas, "you might make a little one, I suppose."

"How should I do it?" asked Rollo.

"Why, you might take some dry wood from the shed, and wheel it down the lane, and through the gate, into the pasture. Then you might take a spade, and cut up some turf, though that would be rather hard work for you."

"I wish you would cut the turf for me," said Rollo.

"Well," said Jonas, "perhaps I will. Then you must hollow out a little place in the bare spot I make by taking up the turf, and make your pile of wood there, leaving a hole in the middle."

"How can I leave a hole?" asked Rollo.

"Why, you can take three short pieces of board, as long as you intend the height of your pile to be, and stand them up on the ground, so as to leave a three-cornered space between them, and then pile your wood around the three boards."

"So I can," said Rollo.

"Your wood must be small," continued Jonas, "or else you can't pile it very snugly in a small pile. You had better take small round sticks, and saw them short, and lean them up against your boards all around, and so make a snug pile. After the pile is ready, you must bank up a little against the bottom of your heap with the loose earth, and then begin to put on the turf. But that will be a nice business."

"Why?" asked Rollo.

"Because you must fit them carefully all around; and, as the heap will be round, and will grow smaller towards the top, square pieces of turf will not fit. You will have to cut them into shape with a knife. You can get an old knife to cut them with, and so fit them together. But you must fit

them together well, or the air will get in, and your heap of wood will blaze up, and so it will be spoiled for charcoal."

"I can make it tight," said Rollo, "I know. I'll shave away the sides of every turf, till it fits its place exactly."

"There must be some air," said Jonas, "or else the wood will not burn at all. You must leave a few holes around at the bottom, to let a little air in, and then you can plug some of them up, if you find the fire burns too fast."

"Well," said Rollo, "I mean to make some charcoal some day. I'll get my cousin James to come and help me. I'll begin to saw up some wood for it to-morrow."

"But, then, Jonas," he continued, after a moment's pause, "what good will the charcoal do me when I get it made?"

"O, I don't know," said Jonas; "I wasn't thinking of your getting any good from the charcoal. All the advantage would be, the pleasure of making it."

"Isn't there any thing I can do with it," said Rollo, "when I get it made? What is charcoal good for?"

"It makes a very hot fire. They use it



when they want a great heat. Blacksmiths use it in their forges."

"I wish I had a little forge," said Rollo.

"They use it to make gunpowder too," said Jonas.

"How?" said Rollo.

"Why, they take some charcoal, and some sulphur, and some saltpetre, and pound it up together, and it makes gunpowder."

"That's what I'll do with my charcoal," said Rollo, jumping up from his seat. "I'll make some gunpowder. I'll ask my mother to give me some sulphur and saltpetre, and I'll make some gunpowder."

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#### QUESTIONS.

What was the condition of the fire, on the evening when it was left to Jonas to cover up? Describe the arrangements which he made for covering up the fire. What was the shape of the stick of wood? Why was this form convenient for the purpose? What plan did Rollo propose instead of covering up the fire? What objection did Jonas make to this plan? What term did Jonas use to designate the process which would go forward, during the night, under the ashes? What did he say that *combustion* meant? Would any air at all be necessary for the slow combustion? How was the necessary air to get access to the wood? Why could not Rollo catch the fire-flies? How did Jonas describe the process of making charcoal? What did he say were the uses of charcoal? To which of these uses did Rollo intend to put his charcoal, if he should succeed in making any?

## CHAPTER II.

## LAMP-LIGHTING.

ROLLO did not think to ask his father the reason why the philosophers use such learned language, or, as he expressed it, such hard words, for several days. Perhaps he never would have thought of it again, if his father had not happened to use the word *combustible* one evening, which reminded him of the term *combustion*, which Jonas had used. The occasion on which his father used the word was this : —

One evening, Rollo's mother was trying to light a little lamp, to go into her bedroom for something that she wanted. There were, usually, in a little vase upon the mantel-piece, some lamp-lighters, which were long, slender rolls of paper, that Rollo had rolled up for this purpose. They were kept in this vase upon the mantel-piece in order to be always ready for use. But the vase was now empty. The last lamp-lighter had been used ; and so

Rollo's mother folded up a small piece of paper, and attempted to light the little lamp, which she was going to carry into the bedroom, with that.

But the wick would not take fire, and Rollo saw that, while his mother was continuing her efforts to make it burn, the flame of the paper was gradually creeping up nearer and nearer to her fingers. At last, finding that there would soon be danger of burning her fingers, she walked across the room towards a window which was open, still endeavoring to light the lamp. But it was all in vain. She reached the window just in time to throw the end of the paper out, and save her fingers from being burned.

"Why won't it light?" said Rollo.

Rollo's father was sitting upon the sofa, taking his rest after the labors of the day; and when he saw that the lamp failed of being lighted, he said, —

"You will have to get a longer lamp-lighter, unless you have got some spirits of turpentine to put upon the wick."

"Spirits of turpentine?" repeated Rollo.

"Yes," said his father. "In hotels, where they have a great many lamps to light, they



"But it was all in vain," p. 22.





have a little bottle of spirits of turpentine, with a wire running down into it; and, when they take out the wire, a little drop of the spirits of turpentine hangs to the end of it, and they touch this to the wick, and then it will light very quick."

"Why, sir?" asked Rollo.

"Because spirit of turpentine is very combustibile, or rather inflammable."

"That means it will burn very easily, I suppose," said Rollo.

"Yes," replied his father.

"That makes me think of something Jonas said, which I was going to ask you," said Rollo. "He said that, in books, burning was always called *combustion*, and I told him I meant to ask you why they couldn't as well call it *burning*."

"I don't think that Jonas said exactly that," said his father.

"Yes, sir, he did," replied Rollo; "at least, I understood him so."

"It is true, no doubt," added his father, "that, in philosophical books, philosophical terms are very often used, instead of the common language which we ordinarily employ."

"Why are they, father?" said Rollo. "I think the common words are a great deal easier to understand."

"Yes," said his father, "but they are not precise in their signification. They are vague and ambiguous, and so philosophers, when they wish to speak accurately, employ other terms, which have an exact signification."

Rollo looked perplexed. He did not understand at all what his father meant. In the mean time, his mother had brought a fresh bundle of lamp-lighters from the closet, and had lighted her lamp with one of them, and was just going away. As she was going out, however, she said to her husband, —

"Please to wait a minute, until I come back, for I should like to hear what you are going to say."

"Well," said he; "and you, Rollo, may come and sit down by me, and I will explain it to you when mother comes back."

So Rollo came and took a seat on the sofa by the side of his father, saying, —

"Father, I wish you would have a bottle of spirits of turpentine for us to light our lamps by."

"It is not of much advantage in a family," said his father, "where the lamps are lighted in various parts of the house, and only a few in all to be lighted. But where there are a great many, it is quite a saving of time to have a little spirits of turpentine to tip the wicks with. In an illumination they always touch the wicks so, and by that means they can light up suddenly."

"But, father, why will the wick light any quicker?"

"Why, different substances take fire at different temperatures. For instance, if you were to put a little heap of sulphur, and another little heap of sawdust, on a shovel together, and put them over a fire, so as to heat them both equally, the sulphur would take fire very soon, but the sawdust would not until the shovel was very nearly red hot. So if you were to put oil in a little kettle over the fire, and spirits of turpentine in another kettle, and have the fire the same under both, the spirits of turpentine would inflame long before the oil. There is a great difference in different substances, in regard to the temperature at which they inflame."



"What do you mean by *temperature*, father?" said Rollo.

"Why, *heat*," said his father.

"Then why don't you say *heat*?" said Rollo.

His father laughed.

"What are you laughing at, father?" said Rollo.

"Why, that's the same question that you asked me at first, and I promised to wait till mother came before I explained it. So we will wait until she comes."

They did not have to wait long, for Rollo's mother soon returned; and she put out her lamp by means of a little extinguisher which was attached to the stem of the lamp itself. Then she sat down at the table, by the light of a great lamp which was burning upon it, and took out her work.

Rollo's father then repeated to her what he had just been telling Rollo, namely, that different substances took fire at different degrees of heat; and he said that it would be a very interesting experiment to take a long iron bar, and put a small quantity of several different substances upon it, in a row, and then heat the bar gradually, from end to end,

all alike, until it was very hot, and so see in what order the various substances would take fire.

"I would have," said he, "phosphorus, sulphur, sawdust, charcoal, saltpetre, oil, — we should have to make a little hollow in the iron for the oil, — alcohol, spirits of turpentine, and perhaps other things. The phosphorus would take fire first, I suppose, and then perhaps the sulphur, and others in succession."

"Well, father," said Rollo, "I wish you would. I should like to see the experiment very much."

"No," said his father, "I cannot actually try such an experiment as that. I could not get such a bar very conveniently; and, if I had the bar and all the substances, I could not heat the bar exactly equally. It could not be done very well, except in a chemical laboratory. But it would be a very pretty experiment, if it could be performed."

"Is there a very great difference," said Rollo's mother, "in the degree of heat necessary to set fire to these different things?"

"Yes," said Mr. Holiday, "I believe the difference is very great. Phosphorus in-

flames below the heat of boiling water, but it takes almost a red heat to set wood on fire. And iron will not take fire till it is white hot."

"Iron?" said Rollo, with surprise.

"Yes," said his father, "iron will take fire and burn as well as wood, if you heat it hot enough."

"I never knew that," said Rollo.

"The ends of the tongs and of the andirons do not burn," said his father, "simply because the fire is never hot enough to set such a large piece of iron on fire. But if we heat the end of a bar of iron very hot indeed in a furnace, it will take fire and burn; and so, if we take a very minute piece of iron, as big as the point of a pin, a common fire would be sufficient to heat that hot enough to set it on fire."

"Well, father," said Rollo, "let us try it."

"If we had some iron filings, we might sprinkle them in the fire, or even in the flame of a lamp, and they would burn."

"I wish I had some filings," said Rollo.

"Yes," said his father, "they burn beautifully."

"How can I get some?" asked Rollo.

"You can get some at a blacksmith's shop," said his father. "The filings commonly accumulate behind the vice, and you can get plenty of them there. The next time you go by a blacksmith's shop, you had better go in and ask him to give you some."

"Well," said Rollo, "so I will."

"And now do you understand," said his father, "why it is that you can light a lamp more easily when there is a little spirit of turpentine on the wick?"

"Yes, sir," said Rollo. "The spirit of turpentine need not get so hot before it catches fire, and so you don't have to hold the lamp-lighter so long, and burn your fingers."

"Will oil always take fire when it gets to a certain degree of heat?" asked Rollo's mother.

"Yes," said his father, "I suppose so."

"And yet," said she, "the lamp seems to take fire much more easily at some times, than at others."

"Yes," said Mr. Holiday, "that is true. If the wick is cut square across, and rises up only a very little way above the tube, it is very difficult to light it, because the tube



itself and the oil below keep the upper end of the wick cool. It is very hard to heat it, in that case, hot enough to set it on fire. But if the wick projects considerably out of the tube, then it is out of the way of the cooling influence of the metal, and you can heat the upper end more easily."

"I never thought of that," said Rollo.

"That is the operation of it," said his father. "And if you push the wick open a little, so as to separate some of the fibres of it from the rest, then it will take fire more easily still; because the small part which is separated, is more easily heated up to the necessary point, than it was when it was closely in contact with the rest, and so kept cool by it. That is the reason why a thin shaving takes fire so much more easily than the outside of a large piece of wood. The outside of a large piece is kept cool by the parts of the wood behind it, which touch it, while the shaving is heated through very soon."

"I didn't know that before," said Rollo.

"In the cities," continued his father, "the lamp-lighters, that trim and light the street lamps, always cut the wick off, when they

trim the lamps, in a slanting direction, so as to leave a point of the wick projecting up on one side. This point will light very easily, for it stands by itself, somewhat apart from the rest, and so is not kept cool by the rest of the wick. Then, when they put in their great blazing torch, it heats this point to the degree necessary to inflame the oil very easily.

“There is one thing more I want to tell you, and that will be all I have to say about lamps to-night; and that is, to explain to you the philosophy of putting them out. You must understand that two things are necessary to carry on combustion or burning. First, there must be air; and, secondly, the body burning must be kept above a certain degree of heat. Now, if you either suddenly shut off the air from the substance that is burning, or suddenly *cool* the substance, it will go out. For instance, the wick,—you have to heat it to a certain degree before it will take fire. Now, if, after it is burning, you suddenly cool it below that degree, it will go out; or if you shut out the air from it, then it will go out; for it cannot burn un-

less it continues hot, and unless it continues to have a supply of air.

"Now, when we blow out a lamp, we stop the burning by cooling it. The cool air which we blow against it, suddenly cools the upper end of the wick below the point of combustion, and so it goes out. On the other hand, when we put it out by an extinguisher, we stop the burning by means of shutting out the air. Either mode will stop the combustion."

"And how is it when we put on water?" asked Rollo's mother.

"Why, that is somewhat different from either," said Mr. Holiday; "or rather it is both combined. There is something very curious in the operation of water upon fire; that I must explain some other day, for now it is time for Rollo to go to bed."

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#### QUESTIONS.

What was the difficulty in lighting the lamp, as described in the beginning of this chapter? What method did Mr. Holiday say was sometimes adopted in hotels to make the lamps light quick? Why would this make them

light more easily? What question did Rollo ask his father in respect to the use of philosophical language? Why did not his father answer the question immediately? Do all substances take fire at the same temperature? What substances take fire with the least degree of heat? What experiment did Mr. Holiday describe which he said would show this very distinctly? Why could not he perform this experiment? Will iron burn? Why do not bars of iron burn in a common fire? How did Mr. Holiday propose to show that iron would burn? How did he propose that Rollo should get some iron filings?





## CHAPTER III.

## BURNING IRON.

WHEN Rollo went out into the kitchen that evening to get his safety-lamp, — the one which he usually took to go to bed, — he found Jonas sitting at the kitchen table reading ; and, while he was lighting his lamp, he asked Jonas if he would not get him some iron filings the next time he went near any blacksmith's shop. Jonas asked him what he wanted of iron filings, and he said he wanted them to burn. He then repeated to him what his father had said in respect to the combustibility of iron.

"I can make iron filings enough for that experiment in five minutes," said Jonas.

"How ?" said Rollo.

"With a file," replied Jonas.

"Well," said Rollo ; and without waiting to hear any thing further, he ran back to the parlor to ask his mother to let him sit up

long enough to see Jonas make a few iron filings, to try the experiment.

"Won't it do as well to-morrow morning?" asked his mother.

"The scintillations will look brighter in the evening," said Mr. Holiday.

"Very well, then," added his mother, "go; and, if Jonas succeeds in his experiment, ask him to send some filings in to us."

So Rollo went out to find Jonas again. Jonas was gone. Dorothy said that he had gone after a file. In a few minutes, he returned, with a file in one hand, and a large iron spike in the other.

"What is the spike for?" asked Rollo.

"Only for a piece of iron to file," replied Jonas. So saying, he took a small piece of paper out of a drawer, and laid it upon the table. Then he rested one end of the spike upon the paper, and, holding the other end in his hand, he filed it several times in such a way, that the filings fell down upon the paper.

"What fine filings!" said Rollo.

"Yes," said Jonas; "the file is almost worn out, and it does not cut very well."

Rollo looked upon the paper. There were quite a number of small black points upon it, like grains of very fine sand. Jonas then took up the paper carefully by the two sides, bending the two sides upward at the same time, to keep the filings in the middle of the paper. In this way he raised the paper above the lamp, which was upon the table before him, and then, holding it in an inclined position, he let the sand slide down into the flame of the lamp. To Rollo's surprise and delight, it produced a column of sparkles rising up from the flame, which were of the greatest brilliancy and beauty.

"Yes," said Rollo, "they burn, they burn most beautifully. File me some more, Jonas, and let me carry them in and show them to my mother."

Jonas accordingly filed some more filings, and Rollo went in with them very eagerly, to show to his mother.

"Just look," said Rollo; and so saying, he held the paper over the lamp in such a manner as to let the filings slide down into the flame just as Jonas had done. The experiment succeeded perfectly well, as it had done before.

"So you see that it will burn," said Mr. Holiday, "if you heat it hot enough."

"If you make it small enough, you mean," said Rollo.

"I suppose the smallness of the particles is of no consequence," replied his father, "excepting to make it easier to heat them."

"Why, father," said Rollo, "I might put the end of a knitting-needle in the lamp, and I don't see why it wouldn't become as hot as one of the iron filings."

"Because," said his father, "a part of the heat would be conveyed away through the knitting-needle towards your hand, and that would keep the end which was in the flame cooler."

"Would it, sir?" asked Rollo.

"Yes," said his father. "The heat moves off very fast in such a case. You know, if you take a pin between your fingers, and hold the head of it in the lamp, the heat will almost immediately move along the metal, so as to heat the end that you are holding, and burn you."

"Yes, sir," said Rollo; "I have got burned so, very often."

"And of course much more heat would be

conveyed away when the metal was as thick as a knitting-needle."

"Well, father," said Rollo, "suppose a piece of the knitting-needle was broken off, and made so small that it could all be in the flame; then would it burn?"

"How could you keep it there?" asked his father.

"Why—I don't know," said Rollo, hesitating. "Couldn't we contrive some way to keep it there?"

"I don't know of any way."

"Couldn't we put it on the end of the wick?" asked Rollo.

"Yes," said his father, "perhaps we might; but then the end of the wick is cool, and that would cool it."

"O father," said Rollo, in a tone of great surprise, "the end of the wick cool, when it is right in the middle of the blaze!"

"I mean," replied his father, "that it is cool compared with the heat necessary for inflaming the iron. It would feel very hot to your fingers, I have no doubt, for it is filled with boiling oil. But then even the heat of boiling oil is less than that necessary to inflame iron; and so the contact of the



wick with such a piece of iron as you propose, would keep it cool, or rather keep it from getting hot enough to take fire."

"Suppose there was any way," said Rollo's mother, "of suspending a piece of iron as large as the end of a knitting-needle in the lamp; do you think it would take fire?"

"No," said Mr. Holiday, "I don't think it would be heated hot enough. For some reason or other, I don't understand exactly what, a large piece of iron cannot be heated very hot in a small fire, even if the fire entirely covers it. I don't think that any fragment of iron much larger than one of Jonas's filings, could be heated in a lamp so as to take fire. But it could be heated hot enough in a forge. The end of the iron which a blacksmith heats, is often in a state of combustion when he takes it out of the fire."

"There, now, father," said Rollo, "you have not explained to me yet about combustion and burning."

"No," said his father; "we had almost forgotten that. I will explain it now. It will only take a few minutes. Let me see — I began to tell you, didn't I?"

"Yes, sir," said Rollo; "but I couldn't understand very well."

"I was telling you that the language which we use in common conversation, is not precise. It is often ambiguous."

"What does that mean, sir?" said Rollo.

"Why, language is ambiguous when it has two meanings," said his father. "For instance, the word *burning* is used in conversation to express two or three very different things. If you put your finger upon hot iron, you say you have burned it. *Burn*, in that case, is the name of a painful feeling. But if you say you burned a piece of paper, you mean that you put it into the fire, and allowed it to be consumed. In that case, *burning*, instead of being the name of a painful feeling, is the name of a peculiar process by which the paper is consumed and destroyed. Thus the word *burn* is used to denote two very different effects. In fact, it is used in other senses besides these."

"What others, sir?" asked Rollo.

"Why, when we say that a little girl was out in the sun, and burned her face and neck, we do not mean that her face and neck were consumed, or that they felt a painful sensa-

tion, — but that the skin was reddened by the sun's heat. So, when we say that the grass was all burned up in the drought, we mean that it was dried and withered. Thus *burned* and *burning* are used to denote a great variety of effects produced by heat, which effects are very different from each other in their nature. So that, you see, when we are going to speak philosophically of that peculiar process by which bodies are actually consumed by fire, it becomes necessary to have some term to denote that process alone, and not all the other kinds of burning. Now, the word the philosophers use for this purpose is *combustion*. The burning of a stick of wood upon the fire is combustion; but the burning of your finger against a hot iron is not combustion, and the burning of bricks in a brick kiln is not combustion."

"Nor the burning of the grass in the drought," said Rollo.

"No," said his father. "Thus you see that *combustion* is a term of precise and definite meaning; it denotes a particular process, and that alone. But *burning* is a vague and ambiguous term. It has a great many meanings, or, rather, it stands for a



great many different effects, very much unlike in their character. In fact, they seem to be alike in no respect, except that they are all produced by heat."

"Yes, father," said Rollo, "I understand."

"Sometimes," added his father, "the word used in common life doesn't mean enough, instead of meaning too much. For example, there is the word *freeze*. What is the meaning of the word *freeze*?"

"Why, it means," said Rollo, — "freeze? — it means — water turning into ice."

"Yes," replied his father; "when water is cooled below a certain point, it becomes solid. It is just so with lead. Melted lead, when it is cooled below a certain point, becomes solid. The hardening of the melted lead into solid lead, and the hardening of water into ice, as they cool, seem to be phenomena of precisely the same character, and yet the word *freeze* applies only to one. We say the water freezes, but we can't say the lead freezes."

"Why not, sir?" asked Rollo.

"Because it is not the customary use of the word. If we use the terms of common life, we must use them as they are customarily used,

or we shall not be understood. *Freezing*, therefore, will not answer to express all cases of the hardening of a liquid by cold, because that is a term which is only applied to a few of the cases. Now, philosophers want a term which will apply to all the cases of the same kind."

"And what is their word?" asked Rollo.

"*Congelation*," replied his father.

"Congelation?" repeated Rollo.

"Yes," said his father. "When water becomes ice, the philosophers say it *congeals*. So when lead hardens in cooling, they say it *congeals*. Different substances congeal at very different degrees of heat. If we had melted iron and melted lead, equally hot, and let them cool together, the iron would congeal first; and if they continued cooling, by and by the lead would congeal. Water would remain liquid long after lead would congeal; but if it was placed where it would grow colder and colder, the temperature would at last reach the point where water would congeal too. But whatever the liquid is, and whatever the point is at which it changes from a liquid to a solid form, it is called *congealing*."

"And the word *freezing*, then, is only used in respect to water," said Rollo's mother.

"Why, yes," said Mr. Holiday; "we speak of other things freezing beside water, but it is only such things as become solid under great degrees of cold. We say ink freezes, and oil, and if it were cold enough to freeze brandy, or mercury, we should say they were frozen. But substances that harden when they are not very cold, as lead or wax, are not said to freeze.

"Thus you observe," continued Rollo's father, "in common language words are not used in a precise and definite manner. Their meaning is determined by the outward and visible effects that we see, and not by the real nature of the causes. Thus a great many different effects are called *burning*, in common language, because they are all effects produced in various ways by heat. But the terms used by philosophers are definite and precise, each one being confined to one specific process or phenomenon."

"Father," said Rollo, "I want to see the iron filings burn again, and I'm going out to ask Jonas to file a few more."

"Very well," said his father.

So Rollo went out to get Jonas to make him some more filings, and Jonas did so. Presently Rollo returned bringing the paper in very carefully, with the filings upon it. He put them down upon the table, and his father contrived, by bending the paper in different directions, to gather all the filings together into the middle of it, and then, with the point of his penknife, he took up a few of the filings at a time, and let them drop upon the flame of the lamp. The burning of the filings produced, as before, the most brilliant scintillations.

"What bright sparkles!" said Rollo.

"Yes, it is very inflammable indeed," said his mother.

Here Mr. Holiday dropped more filings upon the flame, from the point of his knife.

"Does *inflammable* mean," continued his mother, "that a thing takes fire easily, or that it burns with a great flame when it does take fire?"

"I don't know," said Mr. Holiday; "I never thought of that distinction. Some things take fire very easily, but don't make a great flame. There's sulphur, for instance; it



takes fire before it gets very hot, but it burns with a very small and faint flame."

"Let us try it, father," said Rollo.

"We can't try it very well, because there is no fire. I suppose the fire in the kitchen is covered up. But if there was a fire, and we were to put a little sulphur upon a shovel, and a small piece of paper by the side of it, and hold them over the fire, we should find that the sulphur would take fire before the paper would even begin to be scorched; but it would make only a very small blue flame. The paper would not take fire nearly as easily; but we should find that, when it did take fire, it would make a much larger and brighter flame."

"I wish you would try it, father," said Rollo; "you can uncover the coals in the kitchen, and find fire enough."

"Well," said his father, "I will."

His father accordingly rose from his seat, and asked Rollo to go into the kitchen, and get the shovel, and bring it to the medicine closet. While Rollo was getting the shovel, his father went to the closet, and took down a little jar half filled with sulphur. When Rollo brought him the shovel, he took out a

little of the sulphur upon the point of his knife, and laid it upon the shovel. He also took a small piece of paper, and laid it upon the shovel by the side of the sulphur. Rollo then led the way to the kitchen, followed by his father with the shovel; and his mother came behind.

They opened the coals a little, and placed the shovel upon them. Jonas and Dorothy looked on with great interest, wondering what they were going to do. The sulphur began to melt almost immediately after the shovel was placed upon the coals; and, in a very short time, Rollo observed a faint blue spot on the place where the sulphur had been lying.

"There," said his father, "see what a small flame."

"Yes," said Rollo; "it is nothing but a little blue spot."

"And the paper is just as whole and white as ever it was."

"Let us wait till the paper gets hot enough to burn."

"I don't think it would ever get hot enough to burn," replied his father, "over such a fire as that. I must light it in the

lamp." So he waited a few minutes until the sulphur was entirely consumed, for he said that he did not wish to have any of the fumes get into the room; and then he dropped the paper off from the shovel down upon the hearth, and Rollo picked it up. His father lighted it in the lamp, and then placed it upon the shovel to see it burn, in order that Rollo might compare the magnitude of the flame which was produced, with that of the sulphur. Of course, such a small piece of paper did not make a large flame, but it was four or five times as large as that produced by the sulphur.

"Now, the question is," said Mr. Holiday, "which is most inflammable, — the sulphur, because it inflames most easily, or the paper, because it makes the greatest flame when it does take fire?"

"I should think the paper," said Rollo.

"There is alcohol," said Mr. Holiday, "which takes fire very easily, but it burns with a very pale and light flame. Oil must be heated much hotter before it will burn; but, when it does burn, it gives a large and bright flame; so that oil is good for lamps, it gives so much light when it burns.

"Spirit of turpentine," continued Mr. Holiday, "inflames easily, and burns brightly too. So does phosphorus."

"What is phosphorus?" said Rollo.

"Why, it is a substance that burns very easily. It looks like wax, but it burns very easily, and with a very bright flame indeed. It takes fire before it is as hot as boiling water."

"I wish I had some phosphorus," said Rollo.

"They keep it at the apothecaries', sometimes," said his father.

"I wish you'd buy a little, father," said Rollo, "and bring it home, and let me see it burn. Does it cost much?"

"I don't know," said his father, "how much it costs. Only it is troublesome to keep it. It must be kept under water."

"Why, sir?" said Rollo.

"To keep it from taking fire. Even the sun shining upon it would heat it hot enough to set it on fire."

"O father!" said Rollo.

"Yes," said his father; "and so, for safety, they make it in the shape of sticks, and keep it in a phial filled with water."



"Well, father," said Rollo, "I wish you would get a little in a phial, and let me put a piece of it upon a paper in the sun, and let me see it catch fire."

"I'll think of it," said his father, "next time I go into town. But phosphorus, you see, is certainly very inflammable, because it takes fire very easily, and burns brightly too. But I don't know which would be said to be most inflammable, sulphur or resin; for instance, sulphur inflames the quickest, but resin will make altogether the greatest blaze."

"I should think the resin," said Rollo.

"We can't tell by reasoning about it," said his father; "it depends on the usage of the word. We will go into the other room, and look in the dictionary."

So saying, they all went into the parlor again, and looked into the dictionary, to learn the precise meaning of the word *inflammable*. The definition given was, "easily kindled into a flame."

"Then," said Mr. Holiday, "if this definition is correct, the sulphur and the alcohol are most inflammable, because they are most easily kindled."

Just then the clock struck, and Rollo's mother said, —

“Why, Rollo, it is half an hour past your bedtime.”

So Rollo bade his father and mother good night, and went out into the kitchen once more to get his safety-lamp, to go to bed. He stopped, however, a moment, as he was going out of the door, to say, —

“Now, father, be sure and not forget to buy me some phosphorus.”

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#### QUESTIONS.

What did Jonas say when Rollo told him about burning the iron filings? How did he make the filings? Did the experiment of burning them succeed? Why will not a large piece of iron burn in the flame of a lamp? What did Mr. Holiday say to Rollo's proposal to hold the end of a knitting-needle in the lamp? Why will not the terms that are employed in common conversation answer for philosophical use? What is the meaning of *ambiguous*? What are the different meanings of the word *burn*? What is the difference between the words *freeze* and *congeal* in respect to the extent of their meaning? What question did Rollo's mother ask, in respect to the meaning of the word *inflammable*? What did Mr. Holiday say? What experiment did he perform to illustrate the two meanings? How was the question at last decided?

## CHAPTER IV.

## FIRE IN THE PASTURE.

A FEW days after Rollo's father gave him the instructions on the subject of combustion which are contained in the last chapter, Rollo saw Jonas going across the yard about the middle of the afternoon, with a lantern in his hand. Of course Rollo called out to him with the usual question in such cases, —

"Where are you going, Jonas?"

"I'm going out into the pasture to set some heaps on fire."

"Well," said Rollo, "and I'll go too."

Rollo ran into the parlor to ask his mother if he might go too. He happened to meet his father just coming in at the front door. He accordingly asked him instead.

"Yes," said his father, "but I'm rather afraid to have the heaps set on fire this afternoon. I am afraid that the fire will run."

"Run?" repeated Rollo.

"Yes," replied his father. "Tell Jonas

he must be very careful not to let the fire get away from him."

Rollo ran off in pursuit of Jonas. When he got to the back yard again, he saw Jonas going down the lane, almost out of sight.

"Jonas!" said Rollo, calling out as loud as he could, "Jo — nas!"

So saying, he ran off after him. He clambered over the great gate which led into the lane, because he thought that he could climb over it quicker than open it. As soon as he reached the ground on the other side, he ran on, calling out, —

"Jonas! Jonas!"

But Jonas did not seem to hear him. At any rate, he did not stop. On the contrary, Rollo was himself stopped, by hearing a voice behind him, as if near the house, calling, —

"Rollo! Rollo!"

Rollo turned to see who it was. It was his cousin James, who was running towards him with all speed. Rollo waited for him to come up. James tried to open the gate, but could not.

"Climb over," said Rollo.

So James climbed over, and soon reached

the place where Rollo was standing, and the two boys walked on together. James said that he had come to play with Rollo that afternoon. Rollo said that he was very glad, and he told James that he and Jonas were going to make some fires in the pasture.

The heaps which Jonas was going to set on fire, were heaps of decayed wood, consisting of old stumps, logs, and roots, and other rubbish which he had gathered up from the ground and piled up in the pasture some weeks before. By being left in heaps, so that the sun and air had free access to them, they had become thoroughly dry, and were all ready to burn with a touch. There were not a great many of the heaps, for it was only a small part of the pasture which had such logs and stumps left in it. The place was on the side of a deep dell, with a brook flowing through the middle of it at the bottom. Rollo and James crossed the brook upon a log, and then ascended the steep side of the hill, among the heaps which Jonas was burning.

Jonas had set two heaps on fire, and was just putting a burning brand into the third heap. Rollo and James wanted Jonas to let



them set the heaps on fire. He told them that they might; and the boys accordingly went to work, taking brands from the heaps which were already burning, and carrying them to the others. The heaps were not only very dry, but quite hot, on account of the influence of the rays of the sun beating upon them; and, besides this, there was a fresh breeze blowing, which made the fires burn up very fiercely. The fires which had been first made soon became so hot, that the boys could not get near them to take any brands from them.

Thus they went along from heap to heap, setting them on fire, only Jonas succeeded in setting them on fire much faster than James and Rollo. Jonas looked around at them at one time, and he found them endeavoring to kindle a fire at a large heap which had been built up around a tall stump. The stump was twice as high as Rollo's head. Rollo and James were kneeling down upon the ground, and blowing the end of the brand, by which they were trying to kindle the fire. But they did not succeed. Instead of that, the wind blew the smoke into their faces.

"Make the fire on the windward side," said Jonas.

"Which is the windward side?" said James.

"The side that the wind blows against," replied Jonas.

"Yes," said Rollo, speaking to James, "we have got our fire on the wrong side. Let us move it round to the other side, and the wind will blow it for us."

So they took up their brands, and put them upon the other side of the heap. The wind fanned them a little, but did not make them blaze.

"Just put some dry pieces on," said Jonas, "and leave them. As soon as they get heated a little, they'll blaze."

The boys followed Jonas's direction, and, after putting a few dry pieces upon the smoking brands, they left this heap, and went to another; though they had first to go back to one which was on fire, and get some more brands.

"How do you set them on fire so fast, Jonas?" said Rollo.

"Why, I don't stop to watch them," said

Jonas, "to see them burn. I put a brand down upon the windy side of the heap, and then cover it with dry pieces, and leave it, and let it burn up in its own time. It will burn as soon as it has time to get heated."

"Yes, James," said Rollo; "my father explained it to me. When wood gets heated above a certain point of heat, it takes fire. Sulphur takes fire before it gets heated so hot."

"O Jonas," said Rollo, "why didn't you pile up this heap?"

Rollo had come to a place where there was a long log lying upon the ground, broken to pieces and decayed, and near it several fragments of roots and stumps scattered around.

"O, come away, come away from there, Rollo," said Jonas; "there is a wasp's nest there."

Rollo and James ran off back towards Jonas.

"A wasp's nest?" said James.

"Yes," said Jonas. "I began to pile up that wood, and heard a buzzing under the log; and I looked down, and saw some wasps



buzzing about a hole. We must burn up the wasp's nest."

"Well," said Rollo, "come and do it now."

Jonas was coming to burn up the wasp's nest; but, as he was passing along towards it, his attention was suddenly arrested at seeing that the flames from one of the fires were beginning to spread rapidly upon the ground. There was quite a large circle in the grass, which had been burned over and blackened, and, at the outer edges of it, the flames were still spreading rapidly, — driven by the wind.

"Look! look!" said Jonas; "our fire is running."

"Yes," said James; "it is burning up all the grass."

Jonas ran to the edge of the circle, and began trampling upon the flames, to put them out. The flames were very light, for the grass was thin, and so the fire was easily extinguished at any one spot; but, while Jonas was putting it out in one place, it was spreading in another, and he could not put it out so perfectly but that it would flame up and begin to spread again when he went to





"No," said Jonas, "we must *whip* it out." p. 63.

another place. James and Rollo stood by somewhat frightened, and not knowing what to do.

"We must get some water," said Rollo, "from the brook. I'll go and get a pail."

"No, a watering-pot," said James; "a watering-pot will be best. Let's go and get a watering-pot."

"No," said Jonas; "we must whip it out with bushes. I'll cut some bushes. Come down here with me."

So Jonas ran down to the bank of the brook, where there were a number of low fir-trees growing. Now, the leaves of the fir-tree are very small and slender, but they stand very thick upon the branches, so that they make a very thick and heavy foliage. Jonas cut off a branch of the fir-tree, and gave it to Rollo. Then he cut off another for James, and another larger for himself, and, armed with these, the boys hastened back to the fire.

They began to whip and brush the little line of flame, and they found that they could put it out very easily. Every blow which Jonas struck, extinguished a line of the fire as long as his branch. Rollo and James

threshed the ground with great vigor, too, and they put out a great deal of the fire. In fact, they soon extinguished all the flames which were creeping up the side of the hill from this first fire, except at one end, where it had got into some thistles, which Jonas had mowed down some time before, and which were now lying upon the ground dry and warm, and so thick that they made quite a hot fire. Rollo was whipping upon these thistles, when Jonas said, —

“Stop, Rollo; it is of no use to whip such a hot fire as that; it is only wasting your strength.”

“Then we can’t stop it,” said Rollo.

“Yes,” said Jonas; “wait until it has gone over the thistles, and burned them up, and then it will come to the thin grass beyond, and there we can whip it out.”

So the boys stopped to rest while the thistles were burning, surveying, in the mean time, the large space which had been burned over, and which looked scorched and blackened.

“Now, all that grass is spoiled,” said Rollo.

“O, no,” said Jonas; “it hasn’t hurt the

grass. It has only burned the dry tops and the weeds. The roots of the grass are all safe, and the ashes left by the fire will make them grow all the better next summer."

"Then, Jonas, let's burn the ground all over."

"No," said Jonas; "if so large a surface gets on fire, we can't stop it, till it runs into the fence, and sets that on fire,—or else gets over into the other field."

So saying, Jonas pointed to a large level field or pasture over the fence, where the grass and weeds were much higher than where they were. The grass and weeds in this other field extended back some distance to a piece of woods; and Jonas said that, if the fire got into the woods, he could not tell how far it would go, or what mischief it would do. "So you see we must be sure and not let the fire get away from us," said he.

Just then, Jonas saw that the fire was beginning to spread from another of the heaps; and he went to it to watch it. He said he was going to let it run a little way before he put it out, for he knew that if a piece of the ground around the heap was once burned over,



the fire would not spread again from the heap.

So he waited, and, when the circle from that heap had become as large as he wished, he and the boys whipped it out; and then they went back to the first fire, which was now getting beyond the thistles, so that they whipped that out too. Rollo and James felt much relieved, now that they perceived that, by the aid of their fir-branches, they had the fires so entirely under their control.

About this time, Rollo saw his father coming through the trees, on the other side of the brook. His father had been a little afraid that Jonas would get into difficulty with his fires, and had come out to see. He found, however, that Jonas knew how to manage the business. He took a branch, and began to help the three boys whip the fires, as fast as they spread beyond the limits which they concluded to allow them.

"I didn't know that the grass would burn so before," said Rollo.

"It will not," said his father, "unless it is both hot and windy. This is an illustration of what I explained to you the other day.

When grass is heated above a certain point, it takes fire. Now, when one blade of grass is burning, it does not usually produce heat enough to raise the next one to such a degree of heat that it will take fire; but this afternoon it will; for now the heat of one little tuft burning is enough to heat the next one sufficiently to cause it to take fire, because it is already partly heated by the sun."

"And the wind helps," said Rollo.

"Yes," replied his father, "the wind helps in two ways. It blows up the grass that is burning, and makes a greater fire of it, and then it blows the hot air and flame against the grass next to it. Thus it makes the heat greater, and at the same time drives it against the fresh grass. I presume this fire would not spread at all if there was no wind. You see, in fact, that it does not spread much in any direction, except where the wind blows it."

"And if there *was* a wind, and yet the grass was not hot, would it spread then?"

"No," said his father, "I presume not. For instance, in the evening, when the ground and grass are cool, I don't think the fire



would run on the ground. That is, I don't think the heat of one row of blades would heat the next row enough to make them take fire, unless they were partly heated by the sun beforehand."

"I should like to try it some windy evening," said Rollo.

"There would be the dew in the evening also, which would tend to prevent the fire's running."

By this time, all the heaps had been set on fire, and the circle of fire which spread out from each one had been whipped out ; so that there was now not much danger that the fire would spread, and Mr. Holiday went away. Jonas, however, said that he must stay and watch the heaps, and Rollo and James concluded to stay with him. But, after a short time, they became tired of poking the embers ; and so Rollo proposed to James to go with him, and help him make some charcoal.

"I have learned how they make charcoal," said Rollo.

"Well," said James, "I'll go ; but what good will charcoal do us ?"

"Why, we can make gunpowder out of it," said Rollo.

"Well," said James, "I should like to make some gunpowder very much."

So the boys went away towards the house, to get the wood to make their charcoal.

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#### QUESTIONS.

What objection did Mr. Holiday make, at first, to having the heaps set on fire? How was Rollo arrested when he was in pursuit of Jonas? What were the heaps composed of which Jonas was going to set on fire? In what condition were they in respect to inflammability? Was there any thing besides their dryness which made them particularly inflammable at this time? Describe Rollo's attempt to set a heap on fire. What course did Jonas pursue? Describe the appearances exhibited when the fire began to run. How did Rollo's father explain to the boys the causes which made the fire run in the grass that afternoon more than at any other time? Describe the mode which Jonas adopted to stop the progress of the fire in the grass. Did he always stop it as soon as it first began to run? Why not?

## CHAPTER V.

## THEORY AND PRACTICE.

THERE is a great difference between understanding theoretically how a thing is done, and being able actually to do it; for, in practice, various difficulties are apt to occur, which are not foreseen by one who knows only the theory. Rollo and James found this to be the case, in their efforts to make charcoal. Rollo felt very confident that he understood the whole process perfectly, and that he should find no difficulty whatever in carrying it through successfully. He was not aware how many difficulties occur in the practical execution of what appears beforehand to be attended with no difficulty at all.

"Are you sure you can make charcoal?" said James.

"Yes," said Rollo, "I know I can. Jonas told me every thing which I must do. First we must get some short sticks of wood."

He and James went to the shed, and selected some pieces of wood, which Rollo said would be suitable for their charcoal bed. He put them into a small saw-horse, which Jonas had made for him to saw wood in, and without much difficulty he sawed a sufficient quantity. James put the sticks into Rollo's little wheelbarrow as fast as they were sawed. It was not very long before the wheelbarrow was filled nearly full.

"Come, Rollo," said James; "here is enough."

"No," said Rollo; "let us fill the wheelbarrow full."

"Why, Rollo," said James, "you've got enough already to make a barrel of gunpowder."

"O, it won't all come into gunpowder," said Rollo; "some of the wood will burn up, I expect. You see we are going to have slow combustion."

"Slow what?" said James.

"Slow combustion," replied Rollo; "don't you know what *combustion* means?"

"No," said James.

"It means *burning*; that is, one kind of burning. You see there are a great many

kinds of burning. Combustion is when it burns all up. If you put your finger in the fire and burn it, it doesn't burn up, does it?"

"I suppose it would if I held it in long enough," said James.

"Yes," said Rollo — "but, — there, I think we've got enough now. If you'll be wheeling it along, I'll go and get some fire."

So James wheeled the wheelbarrow along towards the gate, and Rollo went into the house after some fire. He found that the lantern was not there, for Jonas had carried it into the pasture; and as Dorothy said that it would not be safe for him to carry any coals out, on such a windy day, he took some matches of the kind that take fire by being rubbed against any thing hard, and went along after James.

Rollo had intended to ask Jonas to cut him some turf, to cover his charcoal bed with; but he had not done it yet, and so he got a spade to carry along with him, thinking that he and James could cut the turf themselves. The spade was rather heavy to carry, and so he took hold of the handle, and dragged it along, letting the



blade trail upon the ground. He overtook James at the great gate.

They passed through the gate, and went on, James trundling the wheelbarrow, and Rollo following him with the spade. At last, they came to the place where Rollo had determined to have his charcoal bed. It was a smooth piece of grass ground, a short distance beyond the garden, and so far from any fence that there was no danger of setting the fences on fire. It was, in fact, a very suitable place. Rollo had selected it with great discretion.

"And now," said Rollo, "the first thing is to dig up some turf. We want some large pieces of turf."

"What for?" said James.

"Why, to cover up our charcoal with."

"What do you want to cover it up for?" said James. "Besides, I should think you would want to *make* it, before you cover it up."

"Why, that is the *way* we make it," said Rollo; "we have to cover the wood up with turf."

"O, the wood," said James; "you said the charcoal."

"No, the wood," replied Rollo ; " we want to cover up the wood."

"Then it won't burn," said James, "if you cover it all up with turf."

"Yes," replied Rollo ; "it will burn very slowly. We don't want it to burn fast. That is the very reason why we cover it up with turf, to keep it from burning fast."

"I should think it would be best to pour a little water on it," said James, "if it was burning too fast."

"No," said Rollo ; "we must cover it up with turf. Jonas said so. And I must cut it."

So Rollo began to cut turf with his spade. He found it, however, very hard. It is very hard work to cut turf. After he had cut a square place out, it was very difficult to crowd the spade under it, so as to get the piece of turf out. He, however, succeeded in cutting one piece ; and then the next was easier. After working patiently for about a quarter of an hour, stopping occasionally to rest, and to wish that Jonas would come and finish cutting the turf for him, he succeeded in laying bare a spot of ground large enough for his coal bed ; and, on looking at the



pieces of turf which he had got off, he could not but hope that they might possibly be enough to cover his wood with. At any rate, he thought he would try it; for he could cut more, he said, if at last he found that he should want more. He therefore began to pile up his wood in the spot left bare by the removal of the turf.

"We must leave a hole down in the middle," said he to James, "to put the fire in. I ought to have had some boards for it."

Rollo wanted James to go up to the house, and get some short boards; but James said that he did not know where he could find any, and finally Rollo concluded to make the hole as well as he could by leaving a space, in piling the wood. He succeeded pretty well in doing this. In fact, he piled his heap very well, making it compact and snug, and rounding it up on the top as Jonas had directed, so that it could be easily covered with the turf.

"Now," said Rollo, "we will cover it up. You hand me the pieces of turf, James, and I will put them on."

James handed Rollo one large piece of turf, and Rollo placed it against the side of

his heap of wood. He then brought him a second, and Rollo attempted to place it next to the first, but it did not fit very well.

"There, now," said Rollo, "I haven't got any knife."

"What do you want a knife for?" asked James.

"To cut off some of this turf, and make it fit into its place."

"Must you make it fit exactly?" asked James.

"Yes," said Rollo; "so Jonas said. But I can cut it with the spade."

So Rollo laid down the piece of turf upon the ground, and attempted to cut away one side of it with the spade. He could not do it very well. He was not strong enough to do it with one blow, and, in striking down the spade upon it repeatedly, he could not always hit the same place; and so he mangled the edge, and bruised it to pieces. However, it fitted better than it did before, though there was still an interstice left, at the lower corner, between the two pieces of turf and the ground.

"It doesn't fit exactly," said Rollo; "but no matter. There must *some* air get in."

He placed the other pieces of turf in a row around the heap. After he had gone all around, there were some left, but not enough to cover the top over. They, however, covered it as well as they could, and then Rollo said he would kindle the fire and put it in, and then, while it was getting a-burning, he would cut some more turf, and finish covering it.

They had some difficulty in getting fire. In the first place, the match would not light. Rollo did not see any thing to rub it upon but the handle of the spade, and that was so smooth and glossy, from long use, that it did not produce friction enough to inflame the match. Finally, James rubbed one of the matches upon the side of the wheelbarrow, and that lighted it; but then they had no kindling ready, and, of course, as the large sticks of wood could not be lighted by a match, James, after holding it until it was just ready to burn his fingers, threw it down. Then Rollo did what he ought to have done before. He collected together some leaves, and dried grass, and splinters of wood, which he found lying about, so as to have some combustibles ready when the next match

should be lighted. By this means they soon had a little fire at a short distance from the heap of wood which they had prepared for their charcoal bed.

As soon as their fire began to burn, they attempted to move it into the hole in the middle of the heap of wood. They took off the little sticks and chips from the fire, which were blazing at one end, and dropped them one by one into the hole.

"I don't believe the fire will burn down in that hole," said James.

"Yes it will," replied Rollo. "That's the way they always set the charcoal beds on fire."

But, notwithstanding Rollo's confidence, the chips and sticks, though they had burned very freely while in the open air above, did not appear at all inclined to burn in the hole. One reason was, that the boys did not wait long enough for them to get well heated. The ends which were together were on fire, it is true; but the other ends were cold, and the heap of wood was cold, so that every little brand, though it was blazing when the boys took it off the fire, was at once chilled below the point at which combustion con-



tinues, as soon as it was dropped into the hole. Consequently, after they had dropped all the pieces in, they saw nothing but smoke come out, and even the smoke grew dim.

"It is all going out," said James.

"We must make a bigger fire," said Rollo. "I wish I had a pair of tongs here to take out the old sticks, and then we would make a bigger fire."

But Rollo had no tongs; and so he was obliged to take down his pile in part, in order to get the dead brands out of the middle of it. Then they built another little fire. They waited for this until it was much hotter, and so they succeeded at last in getting a little fire to burn in the middle of their heap of wood.

"As soon as it begins to burn pretty well," said Rollo, "I must cover it all up with sods."

"Then that will put it all out," said James, "I know."

"No," said Rollo; "it will only make it burn slow."

"I think it will put it all out," replied James.

Rollo himself had some misgivings whether

his wood would really burn very well, when all covered up with turf, and he thought that at any rate he would let it get well on fire before he put the turf on. In the mean time, he took the spade, and began to cut the turf, to have it ready.

He found it now very hard to cut the turf,—both because he was tired of cutting it, and also because he had now to begin in a new place, as his woodpile covered the place which he had taken the turf off from before. It is always harder to cut the first turf than it is those that come afterwards.

Rollo succeeded in getting one or two more pieces, and as soon as the heap of wood seemed to be pretty well on fire, he put these pieces on over the top; but they were not enough to cover it, and as the fire increased, the flames came up more and more from the spaces left uncovered.

“O dear me!” said Rollo. “I can’t cut the turf fast enough to cover it.”

“Shovel up some earth, and put on,” said James.

So Rollo began to shovel up the earth from the place which he had made bare by taking off the turf, and to throw it upon the



fire. This had an immediate effect in suppressing the flames which were breaking out ; and, by continuing to throw on earth, he at length got the fire fairly subdued. The earth did not cover the heap. It slid down among the interstices of the wood, and smothered the fire, so that pretty soon Rollo thought that the fire was burning slowly enough to make charcoal.

"If we had some water in a watering-pot, that would be better," said James.

"So it would," said Rollo.

"Then we could make the fire burn just as slowly as we pleased," said James.

"Yes," said Rollo ; "let us go and get a watering-pot. We can get back before it burns up again."

"Well," said James ; "and we'll carry up the wheelbarrow and the spade."

So Rollo took the wheelbarrow, and James the spade, and they walked along towards the house, talking about what they should do with their gunpowder when they had got it made. They came at length to a narrow place in the walk, where James walked on before, Rollo following him with the wheelbarrow. Rollo trundled the wheelbarrow

along very close to James's heels, and so James, to avoid it, ran on. Rollo followed, pursuing him, and so James, to escape, ran off upon the grass, to get out of Rollo's way. But Rollo still followed him, both boys making the air resound with shouts of laughter, until, at length, James, finding that he was still pursued, turned round, and planted the blade of the spade upon the ground, just before the wheel of the wheelbarrow. The wheel ran up against it, and was stopped, and thus James was protected.

The boys amused themselves in this way for some time, entirely forgetting about their watering-pot. After satisfying themselves, however, with this fun, they began to move along towards the house. They found Rollo's little watering-pot, and they carried it to the pump to fill it with water. They got into a great frolic at the pump, too. James would hold the watering-pot, while Rollo pumped, and then, when it was full, he made believe try to sprinkle Rollo, to pay him, as he said, for running over him with his wheelbarrow. Rollo would run off around the yard, and James after him, holding up the watering-pot, with the spout ele-

vated, ready to discharge a shower of water upon him, if he could only get near. When he got pretty near, he would tip up the watering-pot, and out would pour the water in a great number of curving jets, which spouted out towards Rollo, as he ran. When the water from the watering-pot was exhausted by this operation, they would go back to the pump, and fill it again. In the mean time, the wood of their charcoal bed was all burning away.

It was an hour, in fact, before they got back to the charcoal bed ; and, when they reached it, it was a mere bed of embers and ashes. The combustion, instead of having been slow, had gone on with great violence and rapidity, and the wood was entirely consumed. Rollo and James looked upon it for a few minutes in silence.

"We'll put it out now, at any rate," said Rollo ; and he took the watering-pot out of James's hand, and began to pour the water upon the burning bed before him. It made a great hissing and steaming ; and, when he had done, the boys had before them plenty of hot mud, made of ashes and water, but no charcoal.

## QUESTIONS.

What preparations did James and Rollo make for their charcoal bed? Did they find it difficult or easy to cut the turf? How did they arrange the wood? Did Rollo begin right to cover the wood with turf? What was the first difficulty which he encountered? What tool would have been best for cutting the turf into the right form? What tool did Rollo attempt to use instead? What was the difficulty in the operation of it? What plan was at length proposed for checking the combustion, instead of putting on a tight covering of turf? Why did they leave their work and go to the house? What detained them on this expedition? In what condition did they find the charcoal bed on their return?



## CHAPTER VI.

## GUNPOWDER.

WHEN Rollo and James went home, it was nearly tea-time, and they found Jonas just coming from the pasture. They told him of the ill success of their experiment in charcoal-making, with countenances expressive of great disappointment and chagrin.

"It is no matter," said Jonas; "you have had your afternoon's amusement, and that's all you want, isn't it?"

"No, indeed," said Rollo; "by no means."

"Why, what else do you want?" asked Jonas.

"Why, we want some gunpowder," said James. "We were going to make our charcoal into gunpowder."

"You needn't have made a charcoal bed for that," said Jonas. "You can get all the charcoal you want to make gunpowder with, out of the kitchen fire."

"The kitchen fire!" said Rollo.



"Yes," replied Jonas. "You can pick up plenty of little black coals in the corners."

"Will they do?" asked James.

"Yes," said Jonas; "why not?"

"I didn't know that they were charcoal," rejoined James.

"Yes," said Jonas.

"And will you help us make our gunpowder?" asked Rollo.

"Why, it is rather a dangerous business," said Jonas.

"Why, we will be very careful, you know, Jonas, not to get blown up," said Rollo.

"O, I'm not afraid of getting blown up with any gunpowder you can make. That wasn't the kind of danger I was thinking of."

"What danger then?" said Rollo.

"Why, danger of getting the sulphur on your clothes, and smutting your face with the charcoal."

"Why, Jonas," replied Rollo, "if we get the sulphur on our clothes, we will brush it off again; and, as to the smutting, we won't touch the charcoal to our faces."

"It is very difficult," replied Jonas, "to have any thing to do with charcoal, without



getting blacked with it. You can hardly look at it without crocking your face."

"O Jonas," said James, "*I* could, I know."

"Then, besides," continued Jonas, "you can't brush the sulphur off your clothes. If you once get it on, some of it will stay, and your clothes will always smell of sulphur whenever you come near a fire. I don't think that your mother would be willing that you should have any thing to do with sulphur and charcoal."

"I mean to ask her," said Rollo.

Rollo went in to ask his mother, but he found that tea was ready, and so he and James went in and took their places at the tea-table. When the boys proposed their plan of making gunpowder, they found Rollo's mother, as Jonas had supposed, quite averse to any such operations. However, when his father came in, and heard their conversation on the subject, he said that he would take charge of the business, and then his mother would have no objection.

"Well, sir," said Rollo, "I'm glad of that; for perhaps Jonas wouldn't know how to make it."

"He can prepare the materials, at any rate," said his father. "So, after tea, you may go out and ask him to get three tea-cups, and to put about three or four table-spoonfuls of sulphur in one, and of saltpetre in another, and charcoal in another. Only the saltpetre and the charcoal must be pulverized."

"Pulverized?" said Rollo; "what do you mean by that?"

"Why, powdered, — that is, pounded up very fine."

"How shall he pound them?" said Rollo.

"In the iron mortar," said his mother.

"Dorothy will give it to him."

"And when they are all ready," continued Rollo's father, "come and tell me."

Accordingly, immediately after tea, Rollo and James went out to give Jonas the directions about preparing the materials. Dorothy gave Jonas the mortar. She also brought out three tea-cups, and put them upon the kitchen table. Jonas picked up from the corner of the fireplace a few small coals, and put them into the mortar, and then took up the pestle.

"O, more," said Rollo; "we want more than that."

"Yes," said Jonas; "but we must take a little at a time."

"Why?" asked Rollo.

"Because," replied Jonas, "if I put much into the mortar at once, I can't make it fine. I must only have a little, and then the pestle and the bottom of the mortar come close together, and so it grinds up the smallest pieces."

When Jonas had pounded up the charcoal which he had put in at first, he poured the black powder out into one of the tea-cups, and then put in more charcoal, which he powdered as before. He proceeded in this way until he had filled one of the tea-cups nearly half full. He then washed out the mortar, and put it down to the fire to dry. Then he took a glass jar, which Dorothy had brought him from the closet, and which was nearly full of a substance which looked like salt, and poured some of it into the mortar.

"Is that the saltpetre?" said Rollo.

"Yes," replied Jonas.

"It looks like salt," said Rollo.

"Yes," rejoined Jonas, "and tastes a little like salt."

Rollo and James both wanted to taste a

little of the saltpetre, and they did. In the mean time, Jonas had poured some of it into the mortar, and was grinding it up with his pestle ; and, when Rollo asked him where saltpetre came from, and what it was for, Jonas said he did not know any thing at all about it, and went on pounding and grinding with his pestle.

Dorothy now brought out another jar, containing sulphur ; and as soon as Jonas had finished pulverizing his saltpetre, and had put it all into its cup, he poured out some of the sulphur into the third cup. The jars and the mortar were now put away, and Jonas got two sheets of wrapping-paper, and put upon the table, for he said he thought it probable that they might want some, in trying the powder.

"I expect your father will want a pair of scales, too," said Jonas.

"What for ?" asked Rollo.

"To weigh out the materials," replied Jonas. "I don't know what the proportions are ; but I suppose that they must be mixed in right proportions."

"What are the right proportions ?" asked Rollo.



"I don't know," said Jonas; "but I suppose your father will know."

"Well," said Rollo, "I'll go and call him."

So Rollo went in, and told his father that they were all ready. He found his father at the library, looking at a large book.

"Come, father," said Rollo.

"Seventy-five parts of saltpetre," said his father, reading out of his great book, and appearing not to pay any attention to what Rollo said, — "seventy-five parts of saltpetre, eleven and a half of sulphur, and thirteen and a half of charcoal. Seventy-five to eleven, that is, about seven to one. Say, six times as much saltpetre as of each of the other two. That will be near enough."

"Come, father," said Rollo again; "we're all ready."

"Yes," said his father, "I'll come."

Rollo returned into the kitchen, and his father followed him. His mother came, too, for she wanted to see them make the gunpowder. Jonas asked Mr. Holiday if he should want a pair of scales.

"No," said he; "we can guess at the pro-

portions near enough. We can't expect to make very good gunpowder."

"Why not, sir?" said Rollo. "The things are all good that we are going to make it of."

"Very likely," said his father; "but we cannot make them fine enough,—nor mix them intimately."

"Why, father," said Rollo, "Jonas has made them very fine indeed."

"Yes, I have no doubt that he has pulverized them as well as it can be done in a mortar. But it is not possible to make them as fine in that way as they do in the powder-mills. Then, to mix them properly, they ought to be wet and ground together a long time. We can't stop to do that.

"And now, first," he continued, "I want you all to observe how these various materials will burn by themselves, and then see how differently they will burn together."

Mr. Holiday then took up a coal of fire, and put it upon the shovel, and he asked Jonas to hold it for him in the fireplace, under the throat of the chimney, so that the smoke and fumes might not come out into the room. He then took from the cup which



had the sulphur in it, a little of the sulphur upon the point of his knife, and laid it down gently upon the coal of fire. It burned with a very small and faint blue flame. It burned very slowly, and the flame continued for some time; but the flame was not much bigger than the sulphur itself which caused it.

He then tried the same experiment with the saltpetre. The effect was very different, though in this case there was scarcely any flame. It made a little faint flash, accompanied with a slight crackling sound. Then he tried the charcoal, but it did not appear to burn at all. It lay in a little black heap upon the burning coal, just as Mr. Holiday put it on. After a time, however, it began to grow red upon the under side, and finally became red throughout; and then it could hardly be distinguished in appearance from the coal which it was lying upon.

"So you see," said Mr. Holiday, "that these three ingredients are not very combustible by themselves; at least, they burn very quietly, and with very little flame. Now, we will mix them together. We want a tea-spoon, Dorothy."

Dorothy brought a tea-spoon.

"And the mortar. I can mix them better in the mortar."

So Dorothy brought the mortar, too. Mr. Holiday measured out six tea-spoonfuls of saltpetre from the cup which contained that ingredient, and put it into the mortar.

"There must be about six times as much saltpetre as sulphur and charcoal," said he. "That is not exact, but it will be near enough, I presume. Now, I will put in one tea-spoonful of sulphur and one of charcoal. I suppose, however, I ought to go by the weight, and not by bulk."

"What do you mean by that, sir?" said James.

"Why, it ought to be six times as much saltpetre by weight, and not by measure. It wouldn't take six tea-spoonfuls of saltpetre to weigh six times as much as one tea-spoonful of sulphur, I presume; for I should think saltpetre is much heavier. I suppose saltpetre is heavier than either sulphur or charcoal. So I will put in two tea-spoonfuls of sulphur, and two of charcoal, to make up for their lightness."

"I should think it would be better to weigh them," said Rollo.

"Yes, it would be rather better, but it would take more time, and we will see how our gunpowder burns without being exact in the proportions; and if it does not succeed, then perhaps I will try again, and weigh out the ingredients, and see if it makes the gunpowder any better."

While saying this, Mr. Holiday had been gently rubbing and mixing the powders in the mortar. He said he must rub them gently, for, as the pestle and mortar were both of iron, if he rubbed hard, he might possibly set his gunpowder on fire.

"O father," said Rollo, "I don't believe it would take fire by just rubbing in a mortar."

"No," said his father, "I don't think it would, myself; but it might, possibly. I have heard of powder-mills taking fire by the friction of the mills in grinding the powder,—though I don't suppose it would be possible to set fire to any such powder as we can make, by rubbing it in a mortar. Still it is well to be on the safe side."

After Mr. Holiday had mixed the com-

pound sufficiently, he poured it out of the mortar upon the sheet of brown paper which Jonas had prepared.

"Is that gunpowder?" said Rollo, in a tone of incredulity.

"I think it is somewhat doubtful myself," replied his father.

"It does not look like gunpowder," said Rollo's mother.

This was true. The substance before them was different in its appearance from gunpowder in two respects. It was not *grained* like gunpowder, but was fine and impalpable, like dust. Then it was of a lighter color. Mixing so much saltpetre, which was white, with the charcoal and sulphur, prevented its being so dark as common gunpowder. At least, Mr. Holiday thought that this was the reason, and he suspected that, in some way or other, he had got too much of the saltpetre in his composition. At any rate, the powder looked like nothing but a heap of gray dust.

"The proof of the pudding is the taste," said he; "so we'll try it."

He accordingly took up about half a teaspoonful of the gunpowder, and put it upon



the shovel, and he asked Jonas to hold it in the fireplace, so that, if it did burn, the smoke might go up chimney. Rollo wanted to touch it, and his father gave him leave. So he took up a small coal of fire with the tongs, and touched the top of the little heap. To their great pleasure and surprise, it blazed up suddenly and violently.

"Yes," said Rollo, "it's gunpowder! It's real gunpowder, I do believe!"

"Let me touch some of it," said James.

Mr. Holiday put another half tea-spoonful upon the shovel, and let James touch it. It flamed up like real gunpowder, just as before.

"The great peculiarity of gunpowder," said Mr. Holiday, "is, that it burns without air. Other combustibles, when shut up in a confined space, will not burn. If they are set on fire previously, they go out when they are closely shut up from the air. But gunpowder burns the more violently the more closely it is shut up. There seems to be something in some of the ingredients which takes the place of air; so that, when people drill a hole in a solid rock, and pour gunpowder down to the very bottom of it, in a place where nothing else would burn, and

then ram down pounded bricks into the top of the hole, so that no air can get in, if they get fire to the gunpowder, it will burn there more fiercely than any where, and tear the rock to pieces."

"How do they get the fire down?" asked Rollo.

"They put a wire in," replied his father, "before they put in the bricks; and then, when the bricks are pounded in hard, they draw up the wire, and that leaves a little hole extending down to the powder. Then they pour fresh powder into the hole, and put shavings on the top, and then set the shavings on fire, and run away."

"I should like to see them blow up a rock," said Rollo.

"We must make an artificial rock for our gunpowder," replied his father, "and see if our powder will burst it. I'll try, if you will go into the other room, and get the ball of twine out of the drawer."

While Rollo was gone after the ball of twine, his father took a piece of strong wrapping-paper, which Jonas got for him, and, bending it around over his hand in a peculiar manner, he formed it into a conical sort of cup,



into which he poured the gunpowder which he had made. This paper cup was pointed at the bottom, growing larger and larger upwards. He then folded over the upper part, so as to enclose the powder completely; and, when Rollo brought the twine, he began to wind the twine around it, as if he was going to tie it up. Rollo and James expected that he was going pretty soon to cut off the string, and tie it; but, instead of that, he went on winding it up like a ball. After he had carried the string round a number of times, he began to wind it tighter and tighter, taking care, however, always not to pass the twine over the little tip or apex of the cone. By this means, in a short time the whole paper was covered in every part with the twine, except the apex, which remained exposed.

"There," said he, when he had finished, "I have enclosed the powder now in this ball, and confined it tight. We can imagine this to be a rock. The air cannot get at it. If it burns at all, it must burn by means of its internal composition. Now we will go out and set it on fire. Jonas must get a short board and a few shavings."

While Jonas was gone after the board and

shavings, Mr. Holiday made a little more gunpowder in the mortar for priming, as he said. When it was ready, they went out to the door, where they found Jonas with a board and a little basket of shavings.

Mr. Holiday put the board down upon the ground at a little distance from the door. Then he placed his wound parcel of gunpowder upon the board, with the tip down. With his penknife he made a little opening into the gunpowder at the tip, so that a little of it came out upon the board. He then poured his priming down at the same place, and laid the shavings carefully upon it. He finally folded up a paper, and lighted it in the house, and came up cautiously and lighted the shavings. The others all stood upon the piazza looking on, and Mr. Holiday himself, as soon as he saw the shavings began to burn, retreated to the same place of security. The shavings burned slowly for some time. The flame approached nearer and nearer to the charge ; for a minute, the flame seemed to come from the very apex of the cone, and Rollo had just come to the conclusion that the powder would not go off, when suddenly there was a flash and a great

puff of smoke, and immediately after a loud explosion. The children ran to the spot, and found that the ball in which the gunpowder had been enveloped, was torn all to pieces, and the fragments of the twine were slowly burning.

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## QUESTIONS.

Why was Rollo particularly sorry that he failed in making the charcoal? What did Jonas tell him? What dangers did Jonas anticipate in his making gunpowder? What did his father say to his request? What preliminary arrangements were made? What is the meaning of *pulverize*? of *impalpable*? How did Jonas pulverize the charcoal? How did Rollo find his father employed, when he went to call him? What did his father say that the proportions were? Did he attempt to be exact? Did he suppose that the parts ought to be measured by bulk, or by weight? Which did he think was the heaviest of the materials? How did he make allowance for this? What was the success of the experiment? How did their gunpowder differ from real gunpowder in appearance? In what respect does gunpowder differ from other highly-combustible substances? How did Mr. Holiday confine his gunpowder, to show whether it had the property of burning without a supply of air?

## CHAPTER VII.

## THE ALARM.

AFTER the explosion, James said that it was time for him to go home. It was about sundown. Rollo said that he would go home with him to keep him company, if his mother would let him. She had no objection, and Rollo and James went away together.

Rollo went with James to the door of the house where James lived, and then, bidding him good night, he left him, and began to return. When he had got about half way home, he saw a lady and a gentleman coming along the road. As he approached nearer to them, he found that it was his father and mother, taking a walk. Rollo joined them. They said, however, that they had walked far enough, and so in a few minutes they turned round, and went towards home.



"Didn't our gunpowder go pretty well, father?" said Rollo.

"Yes," replied his father, "better than I expected it would, without being more accurate in our proportions."

"It was a very good experiment, I think," said Rollo.

"Yes," replied his father, "it was a good experiment, and it will prove useful to you, if it impresses upon your mind the nature of that property of gunpowder on which its power depends, namely, that its combustion is within itself. It doesn't need the outward air."

"Yes, sir," said Rollo.

"There are other things that are more inflammable than gunpowder; that is, they will take fire more easily, and make a greater flame; but they cannot burn unless they have air. There is phosphorus, for example; it will take fire a great deal more easily than gunpowder, and I believe it will make a greater flame; but it must have air, and it can't burn any faster than fresh air can get to it."

"Then phosphorus will take fire easier than gunpowder," said Rollo's mother.

"Yes," said Mr. Holiday ; "that is, with a less degree of heat. I presume that, if I were to rub phosphorus in a mortar, it would almost certainly take fire. These friction matches are made of some composition of phosphorus, and the heat of rubbing the end upon a board is enough to set the composition on fire. But gunpowder would not burn by being rubbed so. But still, though less heat is required to inflame phosphorus than gunpowder, still air is necessary for the phosphorus, and it is not necessary for gunpowder ; so that gunpowder will burn in confined places when phosphorus will not.

"Suppose, for instance," continued Mr. Holiday, "that we had a barrel of phosphorus and a barrel of gunpowder, both open at the top, and were to set them on fire. The gunpowder would burn at once from the top to the bottom at a single flash, without any help from the outward air. The phosphorus would take fire on the top, and burn down gradually, as fast as the air could come to the flame. It would burn very fast and furiously, and I think it likely it would make, in all, a greater flame than the gunpowder. But then it would burn gradually, and



only as fast as it could get a supply of fresh air; so that if, while it was burning, men were to come and cover it all over with wet blankets, so as to keep away the air, it would smother it, and put it all out."

"The *water* of the wet blankets would put it out," said Rollo.

"No," said his father; "it would be the same with any thing dry, if it would keep out the air. I presume, if a great quantity of dry sand was poured over it, it would put it out. But wet blankets or dry sand put over a barrel of gunpowder, even if we could have time to do it, would have no effect at all in stopping the burning; for the burning is not dependent upon the outward air at all; the combustion is entirely within itself; that is the essential peculiarity of gunpowder, on which all its powers depend."

"I don't see why it should burst open what it is confined in, after all," said Rollo's mother.

"Nor I," said Rollo. "I should think it might burn up, without tearing things to pieces."

"I don't know myself," replied Mr. Holiday, "exactly why it has such an expansive

force. I'll look in some book, when I get home, and see if I can find an explanation of it. But, at any rate, you see the difference in the manner of its burning. Now, there is wood, for example; it burns by degrees, as fast as the fresh air can come to it. When you put a stick of wood upon the fire, if it is dry and warm, and the fire is hot, first the outside takes fire. This burns because the air can get access to it. But the inside does not burn at all. If we were to take a stick off the fire, after it had been burning for half an hour, and saw it in two, we should find the middle as sound and solid as ever."

"Should we, sir?" said Rollo; "I should expect to find it all black coals."

"No," replied his father. "The blackness only extends in a very little distance; and the wood within is not burned any faster than the outside gets burned off out of the way, so as to let the air come to the inner layers, one after another."

"And there is a very curious contrivance in nature," continued Mr. Holiday, "for supplying the fire all the time with fresh air."

"What is it?" asked Rollo's mother.

"Why, air is so constituted, that heat swells it, and makes it lighter; so that the air that is next to the outer layer of the wood, when the wood first begins to burn, becomes heated, and swells, and so, growing lighter, it immediately rises and goes out of the way, and a new supply of good fresh air comes in to take its place. By the time that this is no longer good to promote the burning, it gets heated and rises; and so there is a constant stream of hot air, that has passed through the fire, rising, and fresh air coming in to take its place. That is the reason, Rollo, why we have chimneys in a house. A chimney is nothing but an opening over a fire, so that the air can rise up through it as fast as it passes through the fire, and all the smoke and sparks pass up too."

"I thought a chimney was only to let the smoke up," said Rollo.

"No," replied his father, "that is not all, by any means. If a fire made no smoke, it would still be almost as necessary as it is now to have a chimney. In fact, some fires do not make any smoke; some kinds of coal, dug out of the ground, do not make any smoke; and charcoal fires do not make

any smoke ; but still it is always necessary in such cases to have chimneys.

"Because," he continued, "you must understand, that air gets changed in passing through a fire, so that it will not answer afterwards either to breathe, or to make a fire burn again ; and therefore there must be some way for it to escape, not only out of the way of the fire, but also out of the room where people want to live and breathe. There is always such a stream of air rising up from every fire, great or small, even from a lamp."

"Why, father, is a lamp a fire?" said Rollo.

"Certainly," said his father ; "it is a small fire made by burning oil on the top of a wick, and the hot air rises in a constant stream above it. So in a room, if there was no chimney over the fire, all the air that had passed through the fire, and become heated, would ascend to the top of the room. I saw the proof of this once in a very singular manner."

"How was it, sir?" said Rollo.

"It was one day when I was travelling. It was in the winter. I came to a hotel,



and was going up stairs to my room just before dinner. When I got to the head of the stairs, and was about going along the passage-way to my room, I saw, a little way before me, a door open, which led into another room; and there was a thick stream of white smoke, pouring out in the most beautiful manner, at the upper part of the door, and falling up to the ceiling."

"Falling up!" said Rollo.

"Yes," said his father. "It looked precisely like a little waterfall, falling up. There was no smoke at all coming out, except close to the top of the door; and, as soon as it got out, it went up to the ceiling of the entry, and from that it spread all around like water. It was very beautiful, but I had not time to stop to admire it, for I presumed that the room was on fire."

"And did you cry fire?" said Rollo.

"No," replied his father. "It is never best to call out for help, unless you are sure you need it. My room was very near. I remembered that my pitcher was full of water in my wash-stand. I ran and got the pitcher, and went into the room which the smoke was coming from. I saw

a great blazing by the side of the fire place."

"And did you run and pour your water on?" said Rollo.

"No," replied Mr. Holiday; "I didn't pour it on, for in that case a great deal of it would have all run down upon the floor, and been wasted. I went up to the place, and put my hand into the pitcher, and began to sprinkle the water on as fast as I could, and it put the fire right out at once."

"What was it that was burning?" asked Rollo.

"A basket of chips," replied his father.

"A basket of chips!" repeated Rollo.

"Yes," replied his father. "It seems that the man who occupied that room had gone out without taking down his fire, and he had left a small basket, with a few chips in the bottom of it, near the corner. Now, while he was gone, one of the sticks of wood had burned off, and the two ends outside of the andirons, not having been burned at all, were heavy; and so the ends of the stick fell over, one on one side and the other on the other. The stick which fell over towards the basket, threw a coal against







"We came very near having a fire, sir," p. 113.

it, and set it on fire ; and the basket, being very dry and thin, burned very fast. Scarcely any thing of the size makes a greater blaze than a basket, for it is thin, and of such a form that the air can get to it on both sides."

"That was a narrow escape," said Rollo.

"Yes," replied his father, "I think it was."

"And I expect the landlord thanked you for saving his house from burning up," said Rollo.

"On the contrary," replied his father, "I had a scolding."

"A scolding !" exclaimed Rollo.

"Yes," replied his father ; "I stepped out into the entry, and asked the chamber-maid who was there, if she would go and ask the landlord to come up into that room. When he came, I pointed to the wet and blackened ruins of the basket, and said, —

" ' We came very near having a fire, sir. ' "

"And what did he say ? " asked Rollo.

"Why, he thought that it was my room, and he was quite angry, and began to scold me for being so careless as to leave that basket so near the fire."

"And what did you say?" asked Rollo.

"Nothing," replied his father.

"Nothing!" exclaimed Rollo.

"No, I did not say any thing at all. I listened to hear all that he had to say, and then I went away to my room."

"Why didn't you tell him?" said Rollo.

"I thought I would let him find out in his own way," replied his father.

"And did he find out?" said Rollo.

"Yes," replied his father. "He came to me after dinner, and made a very humble apology. He told me that he was very sorry for what he had said, but that he supposed that that was my room."

"And what did you tell him?" asked Rollo.

"I told him it was of no consequence, — and that a man who allowed himself to condemn before he made inquiry, must expect to fall into some mistakes."

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#### QUESTIONS.

Under what circumstances did Rollo find himself taking a walk with his father and mother? What did Rollo's father say was the peculiar and essential property of gun-

powder? Which is most inflammable, phosphorus or gun powder? How did Mr. Holiday illustrate this? What did Mr. Holiday say about the expansive force of burning gunpowder? By what process are fresh supplies of air furnished to fires? Why does the air which has once passed through the fire rise? What is a chimney for? Would a chimney be necessary if a fire made no smoke? Relate the incident which occurred to Mr. Holiday at the tavern. What example of prudence and presence of mind is furnished by this case? What example of hasty judgment? What example of patient forbearance





## CHAPTER VIII.

## RADIATION AND CONDUCTION.

THERE are two ways by which the heat or the warmth of one body passes off to the other bodies around it. One is called *radiation*, the other *conduction*. Rollo learned the meaning of these terms, and the distinction between them, under the following circumstances:—

One pleasant morning, late in the autumn, Rollo's father said that he was going away on some business, about fifteen miles, and he told Rollo's mother that, if she would like to take a ride, he should be very glad to have her go too. She said that she should like to go very much, and she proposed that Rollo should go with them. Mr. Holiday had no objection to this arrangement, and accordingly Jonas was ordered to put both horses into the carryall, and bring it up to the front door.

"And, on the whole, Jonas," said Mr.

Holiday, "you may go with us too, and that will relieve me of all care of the horses."

There were two seats to the carryall. Rollo sat with Jonas on the front seat, and his father and mother behind. They had a very pleasant ride in the forenoon, but at noon it looked rather cloudy, as if it might be going to rain. Rollo said he was afraid that it would rain before they should get home.

"No matter for that," said Jonas.

"Why, then we shall get wet," said Rollo.

"No matter for that," said Jonas.

They were detained longer than they had expected to be at the place where Mr. Holiday had his business to do, so that it was rather late when they set out on their return home. After they had rode about an hour, it looked still more like rain, and at length Rollo felt a little drop upon his cheek. He said in a complaining tone, —

"There, Jonas, it is going to rain, for it begins to sprinkle now."

"Rollo," said Jonas, "when it rains, the best way is to let it rain; for there is no knowing what good may come of it."

"I don't think any good can come to us,"

said Rollo, "to be out in this storm, and night coming on. I should think that you might drive faster."

Jonas was driving pretty fast, and the rattling of the wheels made so much noise, that Rollo's father and mother did not hear what he and Jonas were saying. Nor did Rollo hear the conversation in which his father and mother were engaged. They were, in fact, discussing the expediency of not attempting to get home that evening, but of stopping, instead, at a little village a few miles before them. As it was growing cold and late, and as there was every appearance of an approaching storm, they concluded to do this; and so, to Rollo's surprise, when they came into the village, his father said to Jonas, —

"Jonas, you may drive up to this hotel on the right; we are going to stop here for the night."

Jonas and Rollo were both glad to hear this. Jonas drove up to the door, and Rollo and his father and mother were soon transferred from their places in the carryall, which were beginning to be cold, and cheerless, and uncomfortable, to a pleasant little par-

lor, with a bright fire in the fireplace, and a table in the middle of the room spread for tea.

Now, it happened that, in this little parlor, the fire was made in what might be called a fireplace-stove, that is, a stove made in the form of a fireplace. It stood out upon the hearth, and from the top of it a stove pipe ascended towards the top of the room, and there passed back into the chimney.

The fire was not built in this room until the party which was to occupy it arrived; but the room became warm very quick. Rollo was surprised that the room became warm so quick, and his father said that such an arrangement as that, namely, a stove standing out upon the hearth, with a pipe above, warmed a room very quick; and one reason was, that it operated by conduction as well as by radiation, whereas a fire in a common fireplace could only warm the room by radiation. Then Rollo wanted to know what *conduction* and *radiation* meant. His father explained them to him while they were waiting for the tea to be brought in.

"There are two ways by which heat moves," said his father. "One way is by

shooting swiftly through the air like light. Hold your hand up before the fire."

So Rollo held his hand up before the fire, as his father had directed.

"Do you feel the warmth of the fire upon your hand?"

"Yes, sir," said Rollo.

"The heat comes from the fire to your hand very swiftly through the air, and makes your hand feel warm."

"How do you know it comes so swift, sir?" said Rollo.

"I will show you," said his father.

So his father looked about the room, and he saw a large book lying upon a table between the windows. He got the book, and brought it to the fire.

"Now," said he, "I will hold the book between your hand and the fire. Then the heat cannot come to your hand."

So Mr. Holiday held the book between Rollo's hand and the fire, and Rollo said that he could not feel the heat.

"Now," said his father, "I will take the book away suddenly, and we will observe what will be the effect. If the heat moves slowly through the air, it will be some time



before you begin to feel the warmth ; but if it shoots through to your hand quick, you will feel it immediately."

So saying, Mr. Holiday suddenly withdrew the book.

"Yes, sir," said Rollo ; "I feel it immediately."

Rollo's father then told him to go back from the fire as far as he could go, and still feel the heat upon his hand, and then he interposed the book between the fire and his hand, just as before. Rollo still found that he could feel the heat from the fire instantly, after his father took the book away.

"Now, that is radiation," said Mr. Holiday.

"Radiation?" replied Rollo.

"Yes," said his father. "Heat radiates from a fire, in all directions, through the air. Heat radiates, too, from all bodies that are hot, or warmer than the air around them. Go and hold your hand near the stove pipe, and see if you can feel the heat radiating from the stove."

Rollo did so. He said he could feel the heat very plainly, though he had to hold his hand nearer than was necessary when he was feeling the heat of the fire.



"Yes," said his father; "that is because the pipe is not so hot as the fire. If the pipe was as hot as the fire, it would be red hot, and then you could feel the radiation as far as you do that of the fire. However, there is some radiation, though the pipe is not very hot. There is always radiation when the thing is warmer than the air around it. There is radiation from your face."

Here Rollo put his hand up towards his face, to try whether he could feel the radiation.

"You can't feel it very well with your hand," said his father, "because your hand is warm, and so that radiates too. But if you hold your hand up very near to your face, perhaps you will feel both to be warmer, for your hand will radiate to your face, and your face will radiate to your hand."

Rollo then put his hand up very near to his cheek, and, after holding it there a minute, he said that he perceived that it felt warm.

"At any rate," said his father, "you understand what radiation is. The heat that comes from the sun is radiated."

"Yes, father," said Rollo, "I understand what radiation is; now tell me about conduction."

"Very well," said his father; "suppose you had an iron crowbar here, and should put one end into the fire, among the burning coals, and let it remain there while you took hold of the other end with your hand. Now, the heat would gradually extend along the bar, from the hot end in the fire towards your hand, through the substance of the iron."

"Would it, sir?" said Rollo.

"Yes," replied his father; "so that at last the end in your hand would begin to feel hot. Did you never try it with a pin in the lamp?"

"Yes, sir," said Rollo; "if I hold a pin in the lamp, it burns my fingers."

"The heat," said his father, "is conducted along through the pin to your fingers. There is a radiation from the lamp at the same time, but the radiation is not enough to burn you at that distance. That is, if you hold your finger near the lamp, as near as the length of a pin, you would feel the warmth produced by the radiation of the heat through the air, but it would not be enough to burn you. But when you take a pin, and put one end into the flame, it conducts off a great deal

more heat than will come by radiation, and your fingers are burned. But then it takes more time for the heat to come along the pin, than for it to come through the air. Thus, in that case, the heat that is radiated, comes very quick, though there is but little that comes, while that which is conducted, comes slowly, but in a great quantity."

"It burns me pretty quick, father," said Rollo.

"Yes," replied his father, "because the pin is very short. But if it was a knitting-needle, or an iron rod longer still, it would take some time for the heat to pass from one end to the other. Heat moves quick by radiation, and slowly by conduction.

"Now, if you should go to the stove," continued Mr. Holiday, "and put your hand upon it, you would burn it by conduction; that is, the heat would be conducted through the iron to your hand. But if you should hold your hand before the fire so near that the heat would come from the coals through the air to it, burning you, then you burn your hand by radiation.

"But you must understand," continued his father, "that there may be conduction

from air, as well as from iron. If you come into a room which is very warm, — that is, where all the air in it is very warm, although the fire may be gone out, — then the warmth you feel comes to your face and hands by conduction from the air which touches your face and hands, just as your hand would be burned by touching the iron that is hot. But if you come into a room where the air is not very warm, but where there is a great blazing fire, then you feel warmed by radiation. Do you understand this ? ”

“ Yes, sir,” said Rollo, “ I believe I do.”

“ I will ask you some questions then, and see if you can answer them. When we toast bread, is the heat applied by radiation or conduction ? ”

“ By — radiation, sir,” said Rollo.

“ Yes ; when we bake bread in an oven, is it by radiation or conduction ? ”

“ By conduction,” said Rollo.

“ Yes,” said his father, “ because you perceive that the fire has all been taken out from the oven, and the bread is baked by the heat of the air which surrounds it. I don’t know but that there may be also some radiation from the sides of the oven, which



are very hot; but no doubt a great deal of the heat is conveyed to the bread by conduction.

"When things are boiled, is the heat applied by radiation or conduction?" said his father.

"By conduction from the water," said Rollo.

"Yes; and when they are roasted?"

"By radiation," replied Rollo.

"Very well," rejoined his father. "I believe you understand the distinction very well. Some other time, I will tell you more about both radiation and conduction. But now I see the tea is coming in."

Rollo looked round, and saw a girl coming in, bringing a waiter with two teapots upon it, and a plate of toast covered with a bright cover, and some other things. She put them all upon the table, and then said to Mr. Holiday, —

"Your tea is ready, sir."

So Rollo and his father and mother took their places at the tea-table to eat their supper. Nothing more was said on the subject, until, just before they rose from the table, Rollo happened to think that his father had



said, at first, that a stove like the one in that room warmed the room both by radiation and conduction, and he asked his father how that was.

“In the first place,” replied his father, “it warms the room by radiation just like any other fire, as you observed by holding your hand before it. But then it also warms the air in the room by conduction, in this way : the heat of the fire heats the iron of the stove and of the pipe. The heat is conducted through the iron to the outside, and there some of it radiates, and the rest is conducted into the air which happens to touch it. Exactly as if you put your hand against the stove pipe, the heat is conducted through to your hand. So it is conducted to the air, which touches the pipe. This air becomes heated, and swells, and so grows light, and rises out of the way, and more cold air comes in to the stove pipe, and gets heated in the same way by conduction. So the air is continually coming up against the stove and pipe at all parts, and it gets heated by conduction, and then rises and floats away over the room, and thus helps warm the room. But in a common fireplace, all the

heat which is conducted off, goes back among the bricks of the chimney, and does not help warm the room. If we had a light tuft of down or cotton, and were to put it near the pipe, perhaps it would be carried up to the top of the room, by the current of air which is heated by conduction of the pipe."

"I wish I had a tuft, to try it," said Rollo. "It would be a very good experiment."

Rollo had no tuft, but he had that evening an opportunity to witness the effect of the ascending current of heated air, in a way which he did not anticipate; for, after tea, they had the table out, for Rollo's father to do some writing, while his mother sat in a rocking-chair near, reading. Rollo wanted to write, and so his father let him have a pen and ink. He said that he would write a little note to his cousin Lucy. It was a very small note, on a little piece of paper, and when he had written down one side, he undertook to dry what he had written by means of the radiation from the lamp, and accordingly held up his paper very near the flame of the lamp, upon one side. The writing, however, did not seem to dry very fast, and, in changing the position of it, he

held it over the flame, though so high that he thought that there was no danger of burning it. But the current of heated air which rises upward from a fire, even so small a fire as the flame of a lamp, is hotter, and rises higher, than most children would suppose. At any rate, before Rollo was aware of the danger, his note was on fire, and he was obliged to turn round suddenly, and throw his paper upon the hearth, to escape burning his fingers.

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#### QUESTIONS.

In what two ways is heat conveyed from one body to another? Relate the circumstances which led Rollo and his father and mother to spend the night at a tavern. What sort of a stove did they find in the little parlor? What is radiation of heat? How did Mr. Holiday demonstrate it to Rollo? How did he prove that heat passes swiftly when it is radiated? How did Mr. Holiday explain and illustrate conduction? By which mode is the greatest quantity of heat conveyed? Which communicates heat most rapidly? What were some of the questions which Mr. Holiday put to Rollo to ascertain whether he understood the distinction? What incident occurred to Rollo in the evening?

## CHAPTER IX.

## RADIATION.

WHEN Rollo awoke the next morning, he found that the storm was over, and he was very glad to see that there was a prospect of a pleasant ride home. He heard a sound as of voices in the yard, under the window of the chamber where he slept. He looked out, and saw a large yard near the stables, with a pump upon one side of it. Before the pump was a large trough, nearly full of water. At one end of the trough there was a cow drinking. Jonas was coming from one of the stables, leading a horse. He was going to let him drink. There was a boy at the pump, at work pumping water, to keep the trough full while the animals were drinking.

"I mean to go down there," said Rollo to himself.

He accordingly finished dressing himself as soon as he could, and went down into the yard.

"Let me pump," said Rollo to the boy.

"Well," said the boy, "and I'll go and be putting down the hay."

So the boy left Rollo at the pump, and went off towards the stable.

"What does he mean by putting down the hay?" said Rollo to Jonas. For Jonas had by this time come to the trough, and his horse was beginning to drink.

"You pump too fast, Rollo," said Jonas; "you make the trough run over."

"Well," said Rollo, "and does that do any hurt?"

"No," replied Jonas, "only it exhausts your strength to no purpose, and by and by you'll be tired, and can't pump at all."

"Then I'll pump slower," said Rollo.

So Rollo began to pump more slowly. Presently the cow went away, and two oxen came, one after the other, from the barn. The boy had let them out. Rollo went on talking with Jonas, pumping very slowly indeed, so that he did not supply water as fast as the animals drank it. The surface of the water in the trough began to subside, and then Jonas called upon Rollo to pump faster.



"O dear me, Jonas!" said Rollo; "you are very hard to be suited."

"Yes," replied Jonas, "I am. If a boy undertakes to do any thing, I want him to do it right, — and that is hard. There are two wrong ways to do a thing, and one right way. First you pump too fast, and then too slow; whereas I want you to pump just right."

"And how should I pump?" said Rollo.

"Why, I want you to have the pumping and the drinking exactly in equilibrium."

"In equilibrium?" repeated Rollo.

"Yes," replied Jonas; "that is, you must supply water from the pump just as fast as the horse and the oxen drink it, and so keep it at the same level in the trough. Thus you'll keep the supply and the consumption in equilibrium."

"Well," said Rollo. So he pumped a little faster, until he got the trough nearly full, and then he noticed the point on the inside of the trough where the surface of the water stood. When he found that the water was rising above that point, he relaxed his efforts a little, until it sank again; and when

he found that it was falling below, he pumped harder. Thus he contrived to keep the supply very nearly equal to the consumption.

It was pretty cold that morning, and, after Rollo had pumped for some time, his hands became cold. So he went into the house. He found his father and mother in the little parlor where they had been the evening before. There was a good fire in the stove, and Rollo held his hands up before it, and warmed them by the radiation. The breakfast-table was set, and before long a girl came in bringing in the breakfast. Among the other things was a little copper tea-kettle, with a heater to set it upon, in order to keep the water hot. The heater was made in this way: There was a sort of pan, of planished tin, large enough for the tea-kettle to be set into it. In the middle of this pan was a round cavity, with a bottom and sides of sheet iron, and there was a piece of cast iron, about half an inch thick, made to fit into this cavity. This piece of cast iron was to be heated in the fire, and then put into its place, with the tongs, and then the tea-kettle was to be put over it, in the

pan, in such a manner that the bottom of the tea-kettle rested upon the top of the heater.

Rollo was very much interested in this apparatus. It was placed upon a corner of the table, near the waiter, and Rollo's attention was first attracted to it by observing that the tea-kettle continued to boil a little on the table. He could not think what made it boil; and, as they were about sitting down to the table, his father began to explain it to him.

"The heater, you observe," said he to Rollo, "furnishes heat to the tea-kettle by conduction, to supply the waste by radiation."

"What, sir?" said Rollo. He did not understand his father very well.

"Why, the tea-kettle loses its heat by radiation principally, and the heater supplies it by conduction, and so one restores what is lost by the other."

"I don't understand it, exactly," said Rollo.

"Well," said his father, "I'll explain it to you presently, after we have taken our seats at the table."

Accordingly, when they were all seated at

the table, Rollo asked his father about the operation of the heater and the tea-kettle.

"Well," replied his father, "I will explain it to you. It is a very good apparatus to illustrate the subject. The tea-kettle is a radiator, and the heater is a conductor, and so they show both modes of conveying heat.

"For," continued his father, "as the sides of the tea-kettle do not come in contact with any thing but the air, they do not conduct away the heat much; for the air does not take heat easily by conduction. But the tea-kettle radiates heat continually. If you put your hand near it, you will feel the heat passing off into the air all around."

Here Rollo, who was seated not very far from the tea-kettle, put out his hand towards it to feel the radiation.

"The tea-kettle would conduct away the heat very fast, if there was any thing touching it all around, which would take heat easily by conduction."

"How fast?" said Rollo.

"Why, if you were to put your hands to it, clasping it all around, the heat would be conducted very fast into your hand, and you

would be burned. Your hands would receive the heat readily by conduction, but the air does not.

"And the tea-kettle," continued his father, "does not radiate the heat very fast, because it is a bad radiator. It is made so on purpose."

"What do you mean by a *bad* radiator, father?" asked Rollo.

"Why, all white, and bright, and polished surfaces radiate very little, — and all dark, and dull, and rough surfaces radiate very fast. So the bright surfaces are called bad radiators, and those that are of dark color and dull, are called good radiators. A bright tea-pot, made of metal, is a bad radiator, and that makes a good tea-pot."

Rollo laughed.

"Its being so bright prevents its radiating the heat of the water within it very fast away, and so the water keeps hot longer. But a stove pipe, which is of dark color, and not polished, is a good radiator. They make them so on purpose. A stove pipe made of some bright metal would look a great deal better, but it would not warm the room so well."



"But, father," said Rollo, "this copper tea-kettle isn't white, nor very bright."

"No," said his father, "it is not very bright; but the surface is polished, you see, somewhat, and this prevents its radiating much. Still it radiates more of the heat than it would if it was of silver, and polished as bright as possible. But a common iron tea-kettle, black upon the outside, would radiate heat much faster than this one."

"There is another thing for you to understand and remember," continued his father; "and that is, that those substances which radiate heat best, also *receive* heat by radiation the best."

"I don't know exactly what you mean by receiving heat by radiation, sir," said Rollo.

"Suppose," said his father, "that we were to cut out a square piece of sheet iron, such as the stove pipe is made of, as large as the palm of my hand, and also a piece of silver, like that which a tea-pot is sometimes made of, and have it polished as perfectly as possible. Suppose, then, that we were to carry both of these out, and lay them down in the sun. Or suppose we hold them up before the fire, so that they would receive

the radiation from the fire. Now, the iron plate would receive the rays of heat more rapidly than the other, and become hot the soonest."

"Would it, sir?" said Rollo.

"Yes," replied his father; "or, if you were to lay them down in the sun out of doors, the effect would be the same."

"I wish we had such pieces to try it," said Rollo.

"Did not you ever observe how cold bright brass andirons are, long after the fire has been built in the fireplace?"

"I have," said Rollo's mother.

"So have I, sir," said Rollo.

"It is because they are polished, and so are neither good to radiate nor to receive radiation. There is another way by which the same principle is illustrated in the spring of the year, when the snow is melting away. Every little leaf, or stick, or insect, that happens to light upon the snow, soon sinks down."

"Yes, sir," said Rollo, "the bees do. Last spring, when I went out in the pasture on the crust one morning, I found a great many bees all down at the bottom of little

holes in the snow. I couldn't think how they happened to get into those little holes."

"The holes were made by the heat of the sun," said his father, "after the bee fell. The bee is of dark color, and his body receives the radiation of the sun much better than the snow, which is polished."

"The snow polished?" said Rollo.

"Yes," said his father. "The snow is composed of flakes, and the flakes of a great number of little needle-like crystals, and all these crystals are polished, so that they do not radiate well, nor receive radiation well. Therefore the heat of the sun has not much effect upon a pure snow bank. But the body of the bee is a good radiator, and also a good receiver of radiation. So it gets warm, and that melts the snow under it, and then it sinks down, so that after a time it gets down to the bottom of a little pit, which it has made itself."

"That's very curious," said Rollo.

"Yes," said his father; "and it is so with every little stick, or sprig, or dry leaf, which happens to fall upon the snow. You could see the effect more distinctly still, if you were to put a bright piece of tin, and a

piece of sheet iron, like stove pipe of the same size, upon the snow in the sun. The iron would receive the radiation, and get warm, and would sink down in the snow, but the tin would not receive the radiation."

"Wouldn't it receive any at all?" asked Rollo.

"Yes," replied his father, "it would receive some, I've no doubt, but perhaps not more than the snow itself would on each side of it; and so the snow that was all around it would melt away as fast as that which was under it, and thus would not make any pit or depression in the snow, as the black iron would."

"But I have observed," said Rollo's mother, "that, in the spring of the year, wherever there are chips or shavings upon the snow, in the yard, it does not melt away under them, as fast as it does in other places."

"Yes, father," said Rollo, "and hay too. Last year, there was some hay left at the post where Jonas tied the horse, and, after the snow was all gone from the rest of the yard, I raked that hay away, and I found a great deal of ice under it."



"Yes," said his father, "I've no doubt of it. That depends upon another principle. But we shall not have time to talk about that now; I will tell you about it after we get into the carryall."

In fact, they had by this time nearly finished their breakfast, and so, after a few minutes more, they rose from the table, and Rollo went out to tell Jonas that they should be ready to go whenever the horses were harnessed. In about fifteen minutes, Jonas drove up to the door, and they got into the carryall, and set out for home.

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#### QUESTIONS.

What did Rollo observe in the yard when he looked out the window the next morning? What were the difficulties in Rollo's pumping? What apparatus attracted Rollo's attention at the breakfast-table? Describe its construction. How did Mr. Holiday explain the operation of it? What sort of surfaces radiate fast? What sort of surfaces radiate slowly? What examples did Mr. Holiday mention to illustrate this? Describe the appearances on the snow in the spring of the year, which were mentioned by Rollo.



## CHAPTER X.

## CONDUCTION.

VERY soon after Jonas had driven out of the village, Mr. Holiday went on with his explanation. Rollo sat, as before, upon the front seat; but, by turning a little in his seat, he could hear what his father said very well.

"Let us see," said his father; "where did we leave off?"

"About the chips," said Rollo's mother.

"And the hay," said Rollo.

"Yes," said his father. "We'll take the case of the hay. Should you think, from what I told you, that hay would be a good or a bad radiator?"

"Good," said Rollo.

"Why?" asked his father.

"Because," replied Rollo, "it is not bright and polished."

"Right," said his father. "And should you think that it would be a good or a bad receiver of radiation?"

"Good," replied Rollo, again.

"Yes," added his father, "because all those surfaces which are good radiators, are good receivers of radiation."

"Only," said Rollo, "the snow doesn't melt under it. It all turns to ice."

"True," said his father. "How thick was the hay in the place that you refer to? that is, how much was there there, and how thick a covering did it make upon the ground?"

"Not very thick," replied Rollo.

"An inch?" asked his father.

"O, yes, sir, more than an inch." Here Rollo held his two hands at a little distance apart, in order to show his father how thick the covering of hay was. It might have been three or four inches, though it is not probable that Rollo's recollection of it was very exact.

"Very well," said his father; "we will call it three inches. Now, you must remember that the sun shines only upon the upper surface of the hay, and, if it is ever so good a receiver of radiation, it is only the upper surface that can be warmed by the direct rays. In order to melt the snow, the hay has not only got to receive the heat from the

sun by radiation on the upper surface, but it has also got to convey it down through this space of three inches by conduction. Now, a substance may be a very good radiator, and a very good receiver of radiation, while it is a very bad conductor. And this is the case exactly with hay. It receives radiation very well, and so the top gets warm under the rays of the sun; but it *conducts* very slowly, and so the bottom keeps cool, although the top is warm. So, you see, a single blade of hay, laid upon the snow under the rays of the sun, would make the snow melt the faster; but a layer of it three inches thick would keep it from melting. A layer of two feet thick would perhaps keep it from melting all summer."

"Why, father," said Rollo, "I should think it would make it warmer."

"No," said his father; "it would keep the warmth from getting to it, because it is a slow conductor. If any thing already warm is covered up in hay, it keeps it from getting cool; if any thing already cool is covered up, it keeps it from getting warm."

"What things are good conductors?" asked Rollo's mother.

"The metals," said his father, "are the best."

"If they are polished?" asked Rollo.

"Whether they are polished or not," replied his father. "I do not know that that makes any difference. Because, you see, in being conducted, the heat moves through the middle of the body, and not along its surface so much; and I don't know that the character of the surface is of much importance. Some metals conduct better than others. The philosophers have a curious kind of an instrument to show the different conducting powers of different substances."

"What is it, father?" said Rollo.

"Why, they have a small iron plate ——"

"Round?" asked Rollo.

"No, square," replied his father.

"I thought plates were always round," said Rollo.

"No," replied his father; "a plate, in philosophical language, is any flat and comparatively thin piece of metal, or other such substance, whatever its shape may be. This plate that I was speaking of is square, or oblong, — I believe it is oblong, — and it is

about as large as my hand, and perhaps half an inch thick.

"In this plate," continued his father, "there are drilled a number of little holes."

"How many, sir?" asked Rollo.

"Why, perhaps eight," said his father. "They are in a row, running along the middle of the plate. The holes are about a quarter of an inch in diameter."

"How much is that?" asked Rollo.

"Why, I should think a common lead pencil might be a quarter of an inch in diameter. The holes are of such a size that you could just put a lead pencil in before it is cut."

"Are the holes bored entirely through the plate?" asked Rollo's mother.

"No," replied his father, "a little more than half through."

"Then," continued he, "they have a number of little rods made of different substances,—such substances as they wish to try, in respect to their conducting power. One is made of brass, one of iron, one of glass, one of wood, &c., and these are fitted into the holes. That is, one end of each rod



is made just large enough to go into its hole, and take out, and yet not be loose in it.

"The upper ends of these rods are hollowed out a little, so as to form small cavities or cups, to put some phosphorus into."

"What is that for?" asked Rollo.

"I'll tell you," said his father. "When they are going to use the instrument, they put all the rods into their sockets, and a little bit of phosphorus into the top of each one, in the cavity. Each piece of phosphorus is about as big as the head of a pin. Now, when these rods are all arranged in this way, the whole apparatus is put upon some hot place, where the whole plate will be heated alike, as, for example, upon the top of a stove. The heat from the stove is conducted into the iron plate; from the iron plate it is conducted into the ends of the rods which are in the sockets; thence it is conducted up the rods towards the phosphorus at the tops of them, only it goes up much more slowly through some than through others. And we can tell which rod conducts the heat the most rapidly, for the phosphorus upon the top of that rod will be the first to take fire."

"Will the phosphorus take fire?" said Rollo.

"Yes," replied his father. "If the stove is pretty hot, enough heat will be conducted up the rods to set the phosphorus on fire. It will look as if the tops of the rods were getting on fire. First one will blaze up, and then another, and then another, according as the rods convey the heat up more or less readily. Perhaps the phosphorus upon the top of the glass or wooden rod will not take fire at all."

"I should think," said Rollo, "that the heat would get up some time or other, if it went up ever so slowly."

"No," said his father, "for some of the heat is conveyed off into the air, up and down the sides of the rods; and so, if the rods are very long, or if they are very bad conductors, they would radiate the heat from their sides so fast, that not enough would get up to the top to set the phosphorus on fire."

"What is the slowest conductor of heat?" said Rollo.

"The air is a very slow conductor," replied his father, "if we can only keep it still. So is wood. A heap of shavings is a

very slow conductor, because it consists of wood and air together."

"How is that?" said Rollo.

"Why, the little interstices between the shavings are all filled with air; and the heat, in passing through, has to go through the thickness of a shaving first, and then through a small space of air; then through another shaving, and then a little more air; and so it works its way along very slowly, and with great difficulty. Therefore, if any thing is covered with shavings, heat neither gets into it nor out of it very easily. It is the same with hay."

"Only the blades of hay are not wood," said Rollo.

"Not exactly," replied his father; "and yet they are very near it. The fibres of the stems of grass are very similar to the fibres of wood. At any rate, they are both slow conductors; so that hay, like shavings, will keep the heat from coming away from any thing that is hot, and from getting into any thing that is cool."

"It is very strange," said Rollo, "that the same thing should be good to keep things hot, and to keep them cool too."

"I don't know," said his father, "that it is very strange. if we consider how it operates. It keeps the heat from passing either way. Hay has no warmth in itself. If you put hay about your feet when you are riding, it will keep them warm, because the warmth is in your feet already, and the hay keeps it from going away. On the other hand, if you put hay around a lump of ice, it will keep it cool, because the ice cannot melt unless some heat gets into it from the sun and air, and the hay impedes the progress of the heat in going in, as well as in coming out. It is just so with furs or blankets. They don't make things warm. They only keep them from getting cold."

"But, father," said Rollo, "if my feet were very cold, and I were to wrap them up in blankets, wouldn't it make them grow warm?"

"Yes," said his father, "they would grow warm, but not because of any warmth in the blankets. The warmth would be produced in your body by the blood, and the blankets would keep it from escaping. That is all. Blankets and furs would be the best things to put up ice in, to keep it cool. They keep







"How did he do it, sir?" said Jonas, p. 153.

the heat from going off from our bodies, and so in the same way they would keep heat from going in from the sun and air to the ice."

"Why don't they keep ice so, then?" said Rollo.

"Because it would be very expensive. Shavings, and tan, and such things, will do nearly as well, and they are a great deal cheaper. Branches of trees would do very well, if the leaves were on. Once I heard of a boy who made an ice-nest, that kept the ice all summer."

"How did he do it, sir?" said Jonas.

"Why, he found a little hollow on the north side of a hill, and he covered the bottom of it with hemlock branches a foot thick. Then he piled up square blocks of ice upon the branches till he made a pyramid of ice as high as his head, and as large on the bottom as a large table. Then he heaped up straw and shavings all around it till the ice was covered very thick. He also contrived to put some sheets of bark over it, to keep the rain off; and thus he kept his ice nearly all summer."

"I should like to try it," said Jonas.

"It would be better for you to make a

little building," said Mr. Holiday; "that would be so much more convenient to get into. You would only have to make the walls double, and fill the space between with tan, or shavings, or straw, or any other substance like that, to keep the heat out."

"Let us do it, Jonas," said Rollo. "I should like a little ice-house very much."

Rollo's mother said that she wished Jonas would; so it was settled that he was to try and see if he could make an ice-house.

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#### QUESTIONS.

What phenomenon that Rollo had observed was it that Mr. Holiday was going to explain when they were seated in the carryall? Did they conclude that hay would be a good or a bad radiator? — a good or a bad receiver of radiation? How, then, did Mr. Holiday account for the snow and ice melting so slowly under it? What was the object of the philosophical instrument which Mr. Holiday described? How was this instrument constructed? What are some of the best conductors of heat? What substances are slow conductors? Describe the plan which the boy devised for keeping ice all summer.

## CHAPTER XI.

## THE RIDE HOME.

AFTER the conversation recorded in the foregoing chapter, the party in the carryall rode on for some time in silence. They were going towards the east, and the morning sun shone very pleasantly upon them, so that it was not cold riding. The air had been frosty early in the morning, but the rays of the sun brought so much warmth with them that they enjoyed their ride very much. After some time, Rollo's father began to speak again of the conductive powers of different substances, thus:—

“I think it probable that the fibres of wool and of fur are better non-conductors of heat than the fibres of wood, and grass, and straw, and other vegetable substances.”

Rollo did not at first understand what his father meant by *non-conductors*. He had not heard him use that term before. So he asked him what it meant. His father told

him that, as people often wanted to employ substances which would not easily conduct heat, they had frequent occasion to use a word adapted to denote such substances as were suitable to such a purpose, and that *non-conductors* was the term which was so used.

"There are two reasons," said he, "why I think it probable that the fibres of the covering of animals are better non-conductors — that is, that they conduct heat more slowly — than vegetable fibres. I should like to have you tell me whether you think they are satisfactory."

"Well, sir," said Rollo, "if you will tell us what the reasons are."

"First tell me of all the substances that you can think of which are composed of animal fibres."

"Fur," said Rollo, "and wool."

"And hair," said his mother.

"Yes," said his father, "and woollen cloth, and blankets, and carpets, and flannel, are made of such animal fibres. Now, can you tell me of any substances which are composed of vegetable fibres?"



"Hay," said Rollo; and then he paused. He could not think of any others.

"Cotton," said his father, "and flax. They are vegetable fibres; and cotton cloth, and linen, and paper, are fabrics made of vegetable fibres. Now, there are two reasons which make me think that the animal fibres are better non-conductors than the vegetable. One is, that they are expressly intended for non-conductors, and therefore would probably be so formed as most perfectly to answer their design.

"For you see," continued Mr. Holiday, "that the wool, and the fur, and the hair, of animals is generally intended as a covering to protect them from the cold. That is, it is intended to keep the heat of the body from passing off, and being wasted in the air. Therefore they must be non-conductors of heat, in order to answer this design. Now, we find that every thing in nature is admirably adapted to answer its design, and therefore we should expect that these substances, which are expressly intended to confine heat, would be the best non-conductors of heat in nature. That is one reason.'

"I think it is a very good reason," said Rollo's mother.

"So do I," said Rollo.

"The other reason is this," continued Mr. Holiday. "All the substances made of the vegetable fibres feel colder to the touch in cold weather than those made of animal fibres. For example, suppose you were to go, in a very cold night, into a room where there was no fire, and put one hand into a bed between the sheets, and the other between the blankets, — which would feel the coldest?"

"The sheets," said Rollo, "a great deal."

"And the reason why they would feel coldest must be," said Mr. Holiday, "that they conduct away the heat from your hand the fastest, which shows that they are better conductors of heat. If you were to put your hand upon iron in such a room, it would feel colder still, because the iron is a better conductor of heat than the vegetable fibres which the sheet is manufactured from.

"In the same manner," continued Mr. Holiday, "a bare wooden floor feels colder than one with a carpet upon it. Now, in the case of a bare floor, it is vegetable fibre which conveys away the heat, and in the

carpet, if it is a woollen carpet, it is animal fibre. But a stone floor would feel colder than a wooden one."

"A painted floor is very cold," said Rollo's mother.

"Yes," said Mr. Holiday; "paint is made of some metallic preparation generally, which is a better conductor than wood. All the metals are much better conductors than wood. That is the reason why they have wooden handles to tea-pots and other such vessels, because a handle of metal would conduct so much heat from the hot water to the hand, that we could not hold it."

"Yes, sir," said Rollo; "and the handle to the little tea-kettle at the tavern was a wooden one. I did not know what it was for."

"It was to keep the heat from coming to your hand when you pour out the water. If the handle had been of copper, it would have been necessary to have a non-conductor to put round it, to keep the heat from coming out of the handle."

"I never heard of such a thing," said Rollo.

"Haven't you?" said his father. "They

make them sometimes, and it is a very ingenious contrivance."

"How do they make them?" said Rollo.

"They make them of some substance formed of animal fibre," said his father, "because that makes the best non-conductor. The article, when ready, can be put upon any handle which is likely to get hot, and, being a non-conductor, it stops the heat from coming from the handle to your hand. You can take up any hot thing by means of it,—unless it is hot enough to burn the animal fibre of which the non-conductor is composed."

"I wish that I could see one," said Rollo.

"Well," said his father, "you can, when you get home. Dorothy has got one, I dare say."

"Dorothy!" repeated Rollo.

"Yes," said his father. "She calls it a *holder*."

"O, a holder," said Rollo. "I did not know you meant a holder."

"Why, a holder is a non-conductor made of animal fibre, and intended only to stop the passage of the heat from the iron handle to your hand."

"I thought it was only to keep our hands from touching the handle."

"No," said his father, "for an iron holder would do that; but an iron holder would soon get hot, and be of no use. That is, an iron holder would allow the heat to pass across very soon to your hand. It must be a non-conducting holder.

"And now," continued Mr. Holiday, "you understand fully the philosophy of the copper tea-kettle. The iron heater was the reservoir of heat. As it was a good conductor, it conveyed the heat rapidly into the bottom of the tea-kettle, and so into the water. The water, being a good conductor, conveyed the heat to the sides of the tea-kettle; but they were made bright and polished, so that they should not radiate it fast into the air. Still, however, they radiated the heat considerably; but the waste was supplied by fresh heat from the heater. At first, the heat came faster from the heater than it was radiated from the sides of the kettle, and so the water was made to boil. But gradually the heater became less hot, and so did not conduct heat so fast into



the bottom of the tea-kettle, — until, at length, there was a time when the supply was just equal to the waste; that is, the heat was conducted in just as fast as it was dissipated by radiation, and the temperature was kept at the same point."

"That was something like my pumping, Jonas," said Rollo.

Jonas nodded his head, but did not speak, as he did not wish to interrupt Mr. Holiday.

"At length," he continued, "the supply by conduction became less than the radiation, and so the water began to cool, and probably, when we left the table, the water had cooled considerably below the boiling point. I think it likely it would have been better to have made the heater of some other substance than iron, — something that is not so good a conductor."

"Why, sir?" asked Rollo.

"Because," said Mr. Holiday, "in that case it would not have communicated its heat so fast, and so the supply would have lasted longer. The iron is so good a conductor, that at first it poured its heat up through the bottom of the tea-kettle in such

quantities as to make the water boil. This was more than was wanted, and the heat at first was wasted. In consequence of this, after a time it became too cool, and did not heat the water hot enough. Now, if it had been made of something which was not a good conductor, it would have parted with its heat more slowly at first, and so the heat would have lasted longer."

"Yes, sir," said Rollo; "and what would have been good?"

"Soapstone is a very good non-conductor," said Mr. Holiday. "But then perhaps soapstone would have got bruised and broken by constant use, and by heating and cooling. It isn't a very hard kind of stone. I think it probable that iron is, on the whole, the best."

Rollo learned nothing more on the subject of heat during this ride, for very soon after this they began to draw towards home. After they had arrived, and the horses had been taken care of, he and Jonas went to look about for a good place to build the proposed ice-house.

## QUESTIONS.

What two classes of non-conductors were the subjects of conversation on the ride home? Name some examples of animal fibres. — of vegetable fibres. Name some examples of fabrics composed of animal fibres. — of vegetable fibres. Which class of substances did Mr. Holiday suppose were best non-conductors? What was the first reason which he gave? — the second reason? What did Mr. Holiday say, further, in respect to the operation of the heater? What was the point of analogy between the operation of the heater and Rollo's pumping? What was the objection to iron as the material for the heater? What other substance did Mr. Holiday suggest? What objection to soapstone did he think of?



## CHAPTER XII.

## THE CONFLAGRATION.

ONE night, some months after the occurrences related in the last few chapters, Rollo had an opportunity of witnessing with Jonas a great conflagration in the city. This incident may very properly be described in this volume, which relates to the phenomena of fire.

Jonas and Rollo had gone to the city on some business for Mr. Holiday. Jonas's orders were to return that night if he could get through with his business; if not, to wait until the next day. It happened that he could not get through with his business, for the man whom he wished to see was not at home. They said he would be at home that night, and that Jonas could see him early the next morning. So they had to spend the night in the city. They took a walk in the evening, doing some errands, and looking at the curious things in the shop

windows ; and at last they went back to the hotel, and retired to bed. Jonas had engaged a room for himself very near Rollo's room.

Rollo did not go to sleep for some time, his mind being somewhat excited by the novelty of the scenes which he had been witnessing, and by the strange place in which he was now trying to go to sleep. At length, however, he got asleep, and dreamed that he was buying a large and beautiful rocking-horse for Nathan, at one of the toy-shops in the city, — and was just mounting the rocking-horse to take a little ride himself, when his visions were disturbed by hearing some strange, confused, and terrifying sounds. He started up and listened. There seemed to be a great sound in the street, and a bright light was flashing and moving upon the wall over his head. He also heard a noise at the door of his room ; and before he had time to consider what all this disturbance meant, he heard Jonas's voice, saying in a gentle tone, —

“ Rollo.”

“ What ? ” said Rollo, eagerly.

“ Don't be frightened. It's only a fire.”

“ A fire ! where ? ” said Rollo.



"I don't know where it is," replied Jonas.

Rollo listened a moment, and he could hear the city bells ringing in very mournful and alarming tones, some near, and some at a distance. There was one belonging to a church nearly opposite to the hotel, which sounded very loud and near. The flashing light upon the wall moved gradually along the room, and then disappeared; and soon after another came in on the opposite side, and moved along the wall in the same manner. Rollo could hear the sound of a great uproar in the street below, consisting of confused but loud and hoarse voices, the heavy rattling of wheels, and a bell which sounded in a very peculiar manner as it moved along the street, as if it was rung by being jolted and jarred.

Rollo and Jonas went to the window to look out. It was a dark and cloudy night, and the window was very high from the street, as Rollo's room was in one of the upper stories of the house. Still they could look down upon the street below, and see that it was filled with a torrent of men, moving along in a hurried manner, the whole mass being illuminated by great torches

which some of the men carried in their hands. They were dragging along a fire engine, which thundered over the pavement as they ran, in the most terrifying manner.

"Let's go and see the fire," said Rollo.

"Well," said Jonas, "we might; only perhaps there may not be any fire. Perhaps it is only an alarm."

"No matter," said Rollo; "let us go and see the alarm."

Rollo knew that to witness the scene of noise and excitement in the street, would interest him very much, even if there was no house on fire.

"Well," said Jonas, "dress yourself as quick as you can, and I'll come in again when I'm ready."

Jonas accordingly went out, and finished making his preparations, and then returned. He required Rollo to put on his great-coat, for he said there would be danger of taking cold in standing still in the chill evening air, to look at the fire if they should find one. When they were ready, they hurried down stairs.

The street seemed to be nearly still when they left Rollo's room; but, when they issued

from the hotel, and stepped out upon the sidewalk, they heard the sound of noise and uproar approaching again. They looked in the direction from which the sound came, and saw a great torch coming along the street, which flamed, and flashed, and illuminated the pavements and the buildings on each side of it. It was followed by a long, double line of men and boys, with other torches and lights at intervals, pulling upon a rope; and farther behind they heard a very heavy, lumbering sound of wheels, and a sort of confused roar of voices mingling with it. It was another fire engine. It approached with great rapidity, and a crowd of men and boys attended and followed it, so large as to fill the street full; and, brushing rudely by Jonas and Rollo on the sidewalk, they filled the air with their loud but hoarse and hollow shouts. "Ahead with her! ahead with her!"

Rollo could not see the engine, for the street was perfectly filled, while it passed, with a dense crowd of men and boys, all running along by its side. Rollo thought that some of them would certainly get run over.

"We'll go a little slower," said Jonas, "till

the engine gets by, and then we shall have more room."

"No," said Rollo, "let's keep up. I want to see where they will go."

"Well," said Jonas, — "O, there's the fire."

Rollo looked forward where Jonas pointed. He saw, through an opening between some tall buildings before them, a faint light in the sky. He saw it, however, only for a few moments; for, as they passed on, the towering walls of the city buildings intervened again, and hid it from their view.

Pretty soon, however, at a turn of the street, they came in view of the light again; and now it looked much brighter than before. It spread upwards, in fact, and illuminated a considerable part of the sky. The sight of the light appeared to animate the engine-men, for they began to run on faster than before, the heavy lumbering of the wheels, and the shouts of, "Ahead with her!" sounding louder than ever. Opposite to where Rollo and Jonas were, there was a light, tossing and dancing upon the top of a tall pole, representing the number *ten* in figures of fire.

"O Jonas," said Rollo, "look at that *ten*."

"Yes," said Jonas, "that is the number of the engine."

"How can they make such fiery figures?"

"Why, they put the lamp in a glass lantern, and they paint the glass black, all except a place left bare, of the shape of the figure which they wish to have, and so the light shines through where the glass is not painted, and that makes the figure of fire.

Just then Rollo heard sounds of new uproar and confusion approaching by another street. He looked in the direction, and saw an engine coming with its long lines of men and its great crowds, its torches and its thundering sounds. The great mass seemed to be coming on with prodigious momentum. They were coming down into the street where they were, and Rollo thought that they would certainly run over No. 10. When they approached the junction of the streets, and saw that the street which they were coming into was already filled up with another engine and the crowds about it, they did not stop, but kept rushing on, and swept round the corner directly into the crowd, where all became mixed and mingled together,



making confusion worse confounded. The crowd became so dense that Rollo and Jonas could not have got along at all, were it not that the crowd itself was moving on ; and so every body that was among them was necessarily borne onwards too.

Just then Rollo heard a very loud and hoarse voice calling out, " Hold on, No. 10 ! Hold on, No. 10 ! "

" What's that ? " said Rollo.

" That's a man with a speaking-trumpet," said Jonas.

" What does he mean by *hold on* ? "

" He means *stop*," replied Jonas. " He wants No. 10 engine to stop here."

The cry of the engineer, " Hold on, No. 10 ! " was repeated and reëchoed by a great many other voices in the crowd, though it was mingled and confounded with many other noises, such as the rumbling of the wheels upon the pavement, the *dinging* of the engine bells, and shouts and outcries from a hundred voices. At last, however, the men and boys attached to No. 10 seemed to understand that they were to "*hold on* ;" and, accordingly, the engine gradually came to a stand, while the other, which was No. 6,

as Rollo learned from a bright figure 6, which he saw tossing about in the air over the heads of those who were drawing it, moved on.

The men about No. 10 took out some long handles, which were secured by the side of the engine, and passed them through some iron rings, fitted to receive them ; and then they all took hold, ten or fifteen men on each side, ready to work the engine. Presently the order was given in the same hoarse and hollow voice from the speaking-trumpet, "Play away, No. 10!" and immediately the men began to work the long handles up and down, with quick and heavy strokes.

"Why, Jonas," said Rollo, "what are they doing?"

"They are working this engine," said Jonas.

"What for?" said Rollo; "they are not near the fire."

"I suppose there is a reservoir near here," said Jonas, "and they are driving the water from it along towards some engine that is near the fire."

"How does the water go?" said Rollo.

"In a hose," said Jonas.

"What is a hose?" asked Rollo.

"It is a long leather pipe or tube. Come out this way, and we shall find it, I suppose, lying along the street."

So the boys pushed their way along beyond the engine, and presently the fire itself burst upon their view in all its glory. It was a store, — one of the stores of a block which extended along the whole street. The front was of brick, and the walls between the different stores of the block were also of brick, so that nothing but the inside and the roof could burn. But the whole interior of the building was on fire, the flames issuing from the windows, and rising in a great, bright, roaring pyramid above the roof, far up into the dark sky. The whole street, except exactly opposite to the fire, where it was too hot for persons to stand, was filled with men whose faces, which were all turned towards the fire, were so brightly illuminated by the light, that Rollo could see them more distinctly than if it had been day. From the midst of a dense crowd just beyond the fire, Rollo saw a slender white thread of water, mounting up in a beautiful curve, and falling over upon the flames. It was the jet

from an engine ; but it seemed to produce no effect upon the flame whatever.

"There is the hose," said Jonas, suddenly.

Rollo turned away from the fire to look at the hose which Jonas pointed out to him, lying upon the pavement. There were a great many persons coming and going, so that he could not see very well ; but he perceived a long pipe of leather lying along the street, in a serpentine direction, and swelled out with the water which the engine was driving through it, as if it was just ready to burst.

"It looks like a snake," said Rollo.

"Yes, and it hisses like a snake too," replied Jonas.

Rollo listened, and he could just hear a hissing sound mingling with all the other noises. He stepped out into the street to see how the hissing sound was produced.

They found that at one of the joints of the hose there was a little leak, and the water spouted from it in a stream, which, though it was very small and slender, mounted as high as Rollo's head. The light from the fire shone so brightly upon this part of the street that Rollo could see the operation very distinctly.



Jonas thought that it was not very safe for them to remain in the midst of the road much longer ; so they went back to the sidewalk, and then began to move along towards the fire. The crowd was so dense that they could not get along very well ; but at last they came to a place where they got up upon some steps, where they could see pretty well, only that Rollo was not tall enough. There were many others standing upon the steps, and Rollo could not see very well over their shoulders. There was, however, a pretty high stone post at the top of the flight of steps, and very near the house, where Jonas thought that perhaps Rollo could sit, if he could get him up there. Rollo was afraid that the place was not wide enough, for there was a ball upon the post, and he could only sit upon that part of the top of the post which was upon one side of the ball.

However, Rollo was so desirous of seeing them put out the fire, that he concluded to try, and so Jonas helped him climb up. He found the place a better one than he had expected. He clasped one hand around the ball, and he rested the other upon Jonas's shoulder, and by this means he found that he



had a firm and comfortable seat ; and the fire, with all the operations connected with it, were in full view before him.

Just as he got established in his seat, he saw a stream from another engine beginning to issue from its pipe, and to rise up towards the building. The man who held the pipe stood upon the top of the engine, and he held it in such a way as to direct it towards one of the upper windows. Rollo could see the red flame through the window, as the shutter had been burned, and all the glass had fallen away ; and, now and then, a great puff of flame would come out, when any momentary change in the wind drove the fire in that direction. The stream of water went directly in at the window. At first, it produced very little effect ; but presently he observed that it began to deaden the redness of the fire just within the window. Rollo thought that this engine was far more powerful than the one which he had noticed before. That still continued to play around behind the building. Rollo occasionally got a glimpse of other jets, coming from engines which were standing on that side. Sometimes these jets came away over the

top of the building, and Rollo could see them broken into drops as their force was spent, but still shooting forward through the flames in regular pulsations produced by the successive strokes of the engines from which they came.

By all these means, the fire was soon perceptibly diminished. The window into which the engine was playing, soon ceased to look red at all ; and presently Rollo saw a tall ladder rising slowly above the heads of the crowd. The lower end of it was nearly under the window, which he had been noticing, while the other end extended almost across the street, and slowly rose. Rollo was expecting every moment to see it fall back upon the heads of the people who were under it ; but it did not. It ascended slowly and steadily, until the upper end passed over, and fell against the building, a little above the window. In a moment, a man appeared at the foot, climbing up the rounds laboriously, as if he was carrying up a burden which made him mount with difficulty. Rollo saw pretty soon that he had an engine pipe in his hands ; and presently he observed that it was the same man whom

he had seen before, holding the pipe of the engine, and directing the stream into the window. The man ascended slowly, dragging up the pipe, and the hose, which was attached to the bottom of it, until, at length, when the hose became so long that he could not lift it any farther, another man took hold below, and presently another; and at last there were four men at different parts of the ladder, all lifting up the hose.

When the man at the top got the pipe up opposite to the window, he pointed it in, and then Rollo could see him looking down, and gesticulating very violently to those below. He seemed to be calling out to them; but there was so much noise that Rollo could not hear what he said. However, presently the man turned round towards the building again, and seemed to be attending to his pipe, and Rollo could see that the water was spouting through it very furiously into the building.

By this time, the fire had been so much deadened, by the various jets of water which had been poured upon it from all sides, that the flames no longer ascended above the roof, but, instead of flame, there was a tall

column of dense white smoke, illuminated by the embers which still glowed below. Rollo and Jonas remained nearly half an hour, watching the progress of the extinguishing of the fire; and then, as Rollo began to feel his seat somewhat uncomfortable, they returned together to the hotel. Rollo said he wondered that the other buildings did not take fire; but Jonas told him that bricks were a pretty good non-conductor of heat, and that, if the walls which divided such a block were of proper thickness, one store was often burned out of the block, without setting fire to the adjoining buildings.

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#### QUESTIONS.

Under what circumstances did Rollo first hear the alarm of fire? What did he observe in the street when he looked out the window? What is a reservoir? How was the water conveyed from the reservoir to the vicinity of the fire? Describe the successive steps of the process by which the fire was extinguished. What did Jonas say regard to the reason why the fire was not communicated to the other buildings of the block?



## CHAPTER XIII.

## THE FIRE IN THE WOODS.

WHEN Rollo and Jonas reached home the next day, Rollo gave Dorothy an account of the conflagration which they had witnessed in the city.

Dorothy did not appear quite so much interested in his narrative as Rollo had expected. There are, in fact, a great many scenes which it is very interesting to witness, but which it is very uninteresting to hear described. This is a distinction which a great many travellers, older and more experienced than Rollo, are apt to forget. Or rather it is one that they do not understand at all. They attempt to describe to their friends scenes of grandeur or sublimity which impressed their minds very strongly when they witnessed them, and are surprised to find that they cannot make a similar impression upon others by means of the description.

Besides, Rollo's account was confused and



indistinct. It is possible to create a strong impression upon the mind by a description of a storm, or of a conflagration, or of any other grand scene. But, then, the description must be given skilfully. It must be clear and distinct, and the several circumstances which contributed most to the production of the general effect, must be presented fully to the mind, and in a regular and proper manner. This Rollo failed to do. He was not experienced in the description of complicated scenes.

Accordingly, when he got through with his narrative, and perceived that Dorothy did not enter at all into the enthusiasm with which he related it, he paused a moment, and then said, —

“Did you ever see a fire in a great city, Dorothy?”

“No,” said Dorothy.

“Well, it is a very grand sight, I can assure you,” said Rollo. “I don’t believe *you* ever saw such a grand sight, in your life.”

“Yes, I have,” said Dorothy.

“What?” asked Rollo.

“A fire in the woods,” replied Dorothy.

"O Dorothy!" said Rollo; "a fire in the woods is nothing at all, compared to a fire in a city. I know, because Jonas and I have built fires in the woods a hundred times."

"O, I don't mean your little bonfires," replied Dorothy. "I mean great fires, when the woods are burning themselves, for miles and miles all around."

"Do the woods get on fire like that?" asked Rollo.

"Yes," replied Dorothy. "I remember one fire, in the woods, when I was a little girl, that came very near burning my father's house. I was quite a little girl."

"How old?" asked Rollo.

"About seven years," said Dorothy. "It was when my father lived in his log-house in the square opening."

"What do you mean by that?" asked Rollo.

"Why, my father made his cut-down square. There were just five acres."

"What is a cut-down?" asked Rollo.

"The piece where he cut down the trees," said Dorothy, "to make a clearing. First they fall the trees, and then it is called a *cut-down*. They let the trees lie all summer,

until they get perfectly dry, and then they set them on fire, and burn them. When my father had got his five-acre piece cleared, he built a log-house upon it, and there we lived. The opening was full of stumps, and the woods were all around it, the stems of the trees standing up thick and close together, like a wall. We could not see out of the opening any where, except a little way down the road."

"And did you live there all alone?" asked Rollo.

"O, no," said Dorothy; "there were my father and mother, and my brother; only my father and brother used to be away almost all the time, at work."

"Well," said Rollo, "tell me about the fire."

"Why, the first that we knew of it, was, that I saw one day a great white smoke rolling up over the tops of the trees, to the north of our house. I asked my mother to come and look at it, and she did. She said she guessed that John Williams was burning off his piece."

"Who was John Williams?" asked Rollo.

"Why, he was one of our neighbors. He

lived about two miles off, and had been falling a piece of woods that spring, for a crop of wheat.

"I watched the smoke for some time," continued Dorothy, "and at length it grew smaller and smaller, and finally I could see nothing but a haze. But, that night, I went out, about nine o'clock, to see if my chickens were all safe, — for there were some foxes about at that time, — and I saw that the sky looked red in that direction; so I knew that the fire had not all gone out."

"Was that the time," interrupted Rollo, "when you had your hen-coop in a stump?"

"Why? did I ever tell you about that?" asked Dorothy.

"Yes," replied Rollo, "you told me about your hen's laying her eggs in an old hollow stump; and then your brother made a coop there, for the chickens."

"Yes," rejoined Dorothy, "that was at the same time. The next morning, I saw the smoke coming up again. It was not so thick as it had been the day before, when the fire first began to burn; but it seemed to spread over a larger space."

"Had the fire got into the woods?" asked Rollo.

"Yes," replied Dorothy. "My father told us, when he got home that day to dinner, that John Williams had let his fire get away from him, and that it had got into a fine growth of sugar maples, and was making sad work.

"My mother asked him if there was not any danger that it would get over to our land; but my father said no, not unless the wind should come in strong from the northward. But he said he thought there would be a shower that afternoon, and that would put it out."

"And was there a shower?" asked Rollo.

"Yes," replied Dorothy; "only the cloud brought more wind than rain, and so it fanned up the fire more than it extinguished it. The rain, in fact, only sprinkled the tops of the trees, leaving all the dry logs, stumps, leaves, and branches, which lay about upon the ground, as dry as ever. After the shower, there was a good fresh breeze all the evening; and about nine o'clock that evening, when we went to bed, the whole sky



in that quarter was of a burning red, as if the heavens were on fire."

"I should have thought you would have been afraid to go to bed," said Rollo.

"No," said Dorothy; "for the wind went down about nine o'clock, and, though the fire looked very bright, my father said it would not spread any more."

"How did it look the next morning?" asked Rollo.

"It only looked smoky," replied Dorothy. "In fact, we never could see any light in the daytime; nothing but smoke. When there was a wind, the smoke increased; and then, if night came on, the sky looked bright and glowing; but if there was not any wind, the fire seemed to die away. Once I thought it was all out."

"And wasn't it?" asked Rollo.

"No," replied Dorothy; "my father said that nothing but a good rain would put it out."

"Why did not your father go," asked Rollo, "and put it out with some bucket of water?"

"Buckets of water, child!" said Dorothy. "do you suppose you can put out a fire in the woods with buckets of water?"

"Why, no," said Rollo, "I suppose not. But they could put it out with such engines as we saw in the city; I know they could."

"You know a great many things that I don't," said Dorothy. "However, we did not have any engines, and so there was nothing to do but to wait for rain. But it happened to be a dry time just then, and there was not any rain for a week; and so the fire continued, sometimes burning up bright, and sometimes dying away, but all the time drawing gradually nearer to our house.

"At last, one night it got so near that my father said that he did not know but that he ought to sit up and keep watch; but the wind shifted before bedtime, and blew it off in another direction, and so he went to bed.

"But about midnight I heard a great noise, which waked me up. I opened my eyes, and looked around, and I saw a great light shining through the cracks."

"What cracks?" asked Rollo.

"Why, the cracks between the slabs."

"Where were the slabs?" asked Rollo.

"Why, the upper part of the house was made of slabs, and there were cracks between them, where I could see out."

"I should think the wind and rain would come in," said Rollo.

"Yes," replied Dorothy; "so they did, when it was stormy, but not enough to do

any harm, because I could always move my bed away from the side where the wind blew; only in the winter the snow used to blow away in to my bed, wherever I put it. But that did not do any harm, because the snow would shake all off again."

"Was not there any window in your chamber?" asked Rollo.

"Why, it was not a chamber exactly," replied Dorothy; "we called it a *loft*. There was a window left in one end, but that was fastened up by a board. So I could only see the light through the cracks."

"What was the noise that you heard?" asked Rollo.

"It was the noise that my father made calling up my brother, and running out. Then, besides, there was a great roaring and crackling of the flames. I got up, and dressed myself, and ran down stairs, and I found the woods all on fire close by our house."

"Why, I thought your house was in the middle of the opening," said Rollo.

"No," replied Dorothy; "it was upon one side of the opening, — pretty near the woods. There was a brush fence running along at the edge of the woods, and a log fence leading from the brush fence to our barnyard. The brush fence was all on fire, and it was blazing up very high; and beyond it, in the woods, the ground was covered

in every direction with heaps of logs, and branches, and old trees, all on fire, and burning furiously. The air was full of smoke and sparks, and the wind was driving them directly towards our house and barn.

"Just then I heard behind me a great crackling, which burst out very loud and suddenly. I looked to see what it was, and I found that the fire had got into the top of a great hemlock-tree, and it was blazing away from the top to the bottom of it. But I had no time to stand looking at it, for my father told me to go and get some water at the spring, and then to watch, and look all about the yard, and if I saw the fire catching any where, to put it out."

"Why did not he do that himself?" asked Rollo.

"O, he had to go," replied Dorothy, "and pull the log fence to pieces; for the fire was creeping along the log fence towards our barn. The barn was full of hay, which my father had got in only a few weeks before, and there was a great haystack in the barn-yard besides; and if these should get on fire, the house would probably go too, for the house was very near."

"And did they get on fire?" asked Rollo.

"No," replied Dorothy; "my father pulled away the log fence, and then the fire could not get to the house and barn in any way except by sparks through the air. And to



keep the sparks from catching on the roof, he got up upon the barn, and my brother got upon the house ; and then my mother brought them water from the spring. So they wet the roofs all over. Once a spark lighted on the haystack, and set it on fire ; but my father saw it smoking, and he came down quick from the barn, and carried the ladder to the haystack, and climbed up, and put it out with his pail of water. There was another spark, too, which caught upon the chips in the yard, near the woodpile ; and I put that out."

"How long did you have to stay ?" asked Rollo.

"O, till the morning," said Dorothy, "and then the wind died all away. And in the course of that day, there came on a rain storm, and it put the fires out. But when I first came out to see it that night, I can tell you the sight was very terrible."

"Yes," said Rollo. "I think it must have been as terrible as the fire in the city."

"It was very lonesome too," said Dorothy ; "only us four fighting such a great fire."

"What should you have done," asked Rollo, "if your house had taken fire, and got burned down ?"

"O, my father would have built us a camp, and we should have lived in that until he could have time to build us another



house. But then I don't know what we should have done for hay all the next winter for our oxen and cows. Father was much more afraid for the barn than for the house."

"O Dorothy!" said Rollo. "Why, there was all the furniture in the house, and that would have been burned up."

"No," replied Dorothy, "there was not much furniture; and what there was we could have got out while the house was burning. The hay was the great thing—the winter's stock of hay."

And thus ended Dorothy's account of the fire in the woods.

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#### QUESTIONS.

To whom did Rollo attempt to describe the fire which he had witnessed in the city? How did he succeed in the description? What was the difficulty? What scene did Dorothy attempt to describe to Rollo? What is a *cut-down*? In what sort of a place did her father live when the fire in the woods occurred? How did the fire first take? What was its progress the first day? What appearances did it present to Dorothy? How did they hope that it would be extinguished? Describe what took place on the night when the fire reached the clearing.

END OF PART III.

















